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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND B. ALFRED RAWORTH.

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Specifications, Conditions of Contract and Forms of Tender may be obtained at the Office of the Board, Embankment, E.C.

Tenders, addressed as noted on the Forms, must be delivered at the Office of the Board not later than Ten a.m. on Wednesday, 14th June, 1916. E 290

(By Order), DUNCOMBE MANN,
May, 1916. Clerk to the Board.

GREAT NORTHERN RAILWAY COMPANY (IRELAND).

The Directors are prepared to receive

Tenders for the Purchase of

One 50 HP. Horizontal, Single Cylinder, Double-acting STEAM ENGINE, by F. Pemberton, Iron Works, Dundalk, 28 in. stroke, and fitted with heavy flywheel, 9 ft. diameter by 12 in., 1¼ in. diameter cylinders, 80 r.p.m., 80 lb. steam pressure, and spare main shaft and driving disc.

Above can be seen on site at the Locomotive Works, Dundalk, as working up to the 1st April, 1916, when it was superseded by electric drive.

Tenders should be delivered, under sealed cover endorsed "Tender for Steam Engine," to the undersigned, not later than Ten a.m. on Wednesday, the 7th June, 1916.

The Directors do not bind themselves to accept the highest or any Tender.

T. MORRISON,
Secretary.

Secretary's Office,
Amiens Street Terminus, Dublin,
18th May, 1916. E 283

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A 1000 B.HP. Triple Expansion, Three Cylinder VERTICAL BELLISS ENGINE, Condensing or Non-condensing.

Two Sets Horizontal SURFACE CONDENSING PLANT, each condenser having a cooling surface of 3000 square feet, with Air Pumping Engines and Circulating Engines.

Six 700 Kilowatt Two-phase ALTERNATORS and EXCITERS.

One additional CIRCULATING ENGINE.

Offers will be considered for the whole or any part of the Plant.

Leave to inspect and other information may be obtained from the undersigned, to whom offers are to be addressed.

The Corporation do not bind themselves to accept any offer.

C. NELSON HEFFORD, Manager.

1, Whitehall Road, Leeds.
May, 1916. E 248

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BOROUGH OF ECCLES.

The ELECTRICITY COMMITTEE REQUIRE an

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BOROUGH ELECTRICAL ENGINEER,
Electricity Works, Cawdor Street, Patricroft, Lancs., and forwarded so as to arrive not later than Wednesday next, the 24th inst. E 268

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Refrigerating ENGINEER, by a cold storage company in a Lancashire city. Must have thorough knowledge of ammonia machinery on the various cooling systems, also experience of electric and suction gas plants. Salary £30 to £35 per month, according to ability and experience. Good prospects of advancement if satisfactory.—Address, stating age, experience, present salary, and enclose copies of testimonials, in confidence.—E 47, BIRCHALL'S Advertising Offices, Liverpool. E 278

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Applications must be made in writing and must give qualifications in full.

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Address, your nearest LABOUR EXCHANGE, quoting No. A 1851. E 242

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WANTED, for a marine engineering works in India, capable of attending to outside repairs. No person already engaged on Government work will be engaged.—Please state age and salary required, also whether married or single, to BOX J 165, LEE and NIGHTINGALE, Liverpool. E 243

Assistant Engineer Required

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QUIRED, in London. Similar experience in engineers' office essential. Must have good knowledge of d.c. systems and printing methods. No man on Government work can be engaged.—Write, or apply, in first instance, to your nearest BOARD OF TRADE LABOUR EXCHANGE, mentioning this paper and No. A 1831. E 245

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by controlled establishment, London District, for general engineering work.—Apply, stating age, experience and salary required, to nearest LABOUR EXCHANGE, mentioning ENGINEERING and No. E 281. No one already employed on Government work will be engaged. E 281

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Wanted, Position by an

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Situation Wanted by Engineer,

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Draughtsman, 18 years d.o. experience in iron and steel works, four years shop. Good practical man; DESIRES responsible POSITION in drawing-office or works.—E 265, Offices of ENGINEERING.

Leading Mechanical and

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A STUDY CONCERNING THE BEST PROPORTION FOR A STREAM-LINE BODY.

By F. W. LANCHESTER.

THE condition governing the best proportion of a stream line or ichthyoid body, such as the envelope of a dirigible or the fuselage of an aeroplane, is one of greater complexity than superficially might appear.

In addition to the question of resistance there is that of directional stability; the relative importance of these depends upon the purpose for which the body is to be designed. Thus in the fuselage of an aeroplane the question of stability is taken care of by the flight organs—namely, the aerofoil, the tail-plane, and other auxiliary laminar organs. In the dirigible the question of directional stability is paramount, and the form (the relation of entrance to run) is, more often than not, designed to conform to the requirements of directional stability. Thus the tail or *run* is sometimes designed of exaggerated length, and the nose or *entrance* is as blunt in form as is consistent with stream line motion. In other cases the form is less distorted, and the tail is provided with dirigent surfaces. In the present article the subject of stream-line form is dealt with from the point of view of resistance only.

Firstly, it may be pointed out that a great deal of latitude exists as to the exact design. In a body whose length in terms of diameter (otherwise expressed as L/D ratio) is about 5 or 6, any good "eyeable" design is nearly as good as the best. For bodies of lower L/D ratio the importance of the exact shape is greater, for, in the limit, we are getting near to the point at which stream-line flow becomes unstable, and when that point is reached the range of variation permissible becomes narrowed, and the resistance responds in an acutely sensitive manner to the slightest change of shape.

Now so long as this critical region or ratio is not approached, the *exact* form is of comparatively small importance. We may then assume a constant *standard of form** as applying to every case, so that with variations of L and D the volume varies as $L \times D^2$. On this basis, in his James Forrest Lecture for 1914, the author gave a curve representing the resistance of stream-line or ichthyoid bodies, which is here reproduced in Fig. 1. *Ordinates* represent a coefficient expressing the resistance in terms of the normal plane of midship section, and *abscissæ* = L/D ratio.

The interpretation of this curve, according to the nature of the problem, gives the solution for best proportion; that is to say, the best L/D ratio to adopt for the particular purpose in question.

There are three different cases or conditions coming within the ordinary range of experience, with three correspondingly different solutions.

(1) *The Fuselage Problem*—namely, to determine the best proportion to adopt when the problem is to provide a passage through the air for a body whose *maximum sectional area* is given.

(2) *The Zeppelin, or Air-Fleet Problem.* To provide the maximum *weight/resistance* or *displacement/resistance* for a given midship section.

(3) *The Dirigible Problem.* To provide for the minimum resistance *for a given displacement.*

The latter two problems, although apparently not greatly different, are in reality quite distinct. In practice they arise from different engineering conditions; in problem (2) it is assumed (just as in the case of our Navy) that a limit of midship section is prescribed by the available housing or docking accommodation. In problem (3) no such limit is postulated.

The solutions to problems (1) and (2) are simple and obvious. Thus the L/D value under condition (1) is given by the point of contact of a horizontal line tangent to the graph, Fig. 1, point A. This gives an L/D value of about 3. Condition (2) is solved by a tangent drawn to the graph passing through the origin, Fig. 1, point B. The L/D ratio is thus about 8 or 9, if we assume the graph as accurately plotted.

Problem (3) is more subtle. The solution is given by the point on the curve, the tangent at which cuts the axis of y at a distance from the origin equal to one-third of the ordinate. This is easily found by trial, as in Fig. 1, point C, but it may be found with precision by means of the graphic construction given in Fig. 2. The result, according to the author's curve, is an L/D value about 6 or 7.

In Fig. 2 the abscissa scale, representing L/D on the right-hand side of the figure, has been transformed into L value for constant volume on the left-hand side. Thus, if volume (displacement) is constant,

$$L D^2 = \text{constant},$$

and

$$\frac{L}{D} = L \sqrt{L} \times \text{constant}.$$

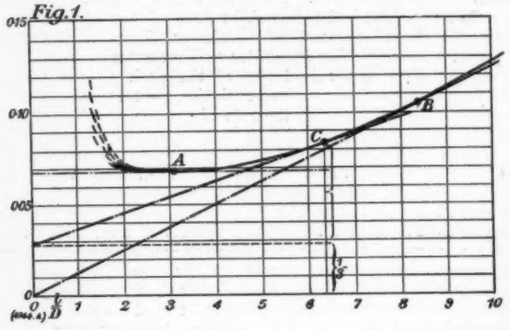
The curve $L^{\frac{3}{2}}$ and the construction used to effect the change of abscissa value is clearly indicated in the figure.

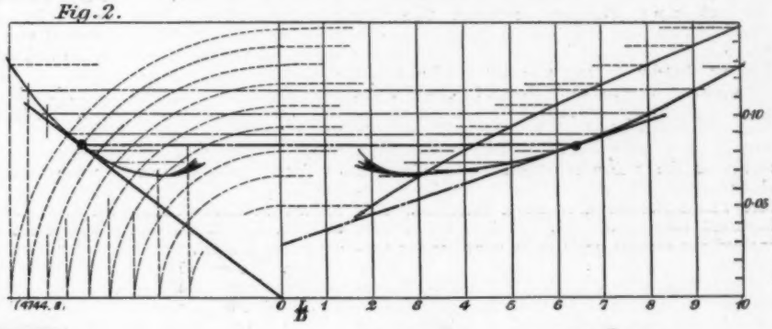
Considering the admittedly general character of the premises assumed, in which the possibility of modification of the form with change of size is ignored, the results accord remarkably with experience. Thus the proportion 7 to 1 is commonly that adopted in dirigible design, and is approximately that used in the French semi-rigid and non-rigid dirigible; it is also a proportion found in Nature, in fishes, Fig. 3.* The proportion 3 to 1 or thereabouts is admittedly correct where the problem is that of providing a passage for a given maximum cross-section. It is of interest to remark also that it is about the average proportion found in Nature amongst birds, examples of which are given in Fig. 4.

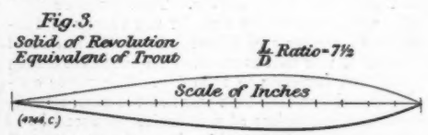
The agreement between the ratio given by the curve (Fig. 1) for the solution of case (2), and the actual L/D ratio used in the German airship fleet (Fig. 5), is probably an accident. The author believes that *if the curve were correctly given* the result would be totally different, and that the actual proportions of a Zeppelin are settled by the designers as a matter of convenience. There would seem to be no reason whatever why, as the case is stated, the length could not be increased indefinitely for any given diameter with a progressive reduction in relative resistance. Thus the displacement will vary ultimately as the length, and the resistance may be reasonably inferred to vary in less ratio than the length.

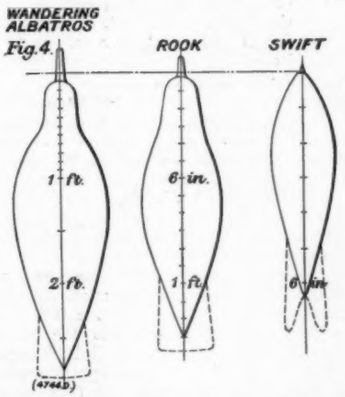
If this view is correct, the curve will be more nearly of the type given in Fig. 6. It will approach a line drawn through the origin asymptotically. In other words, the tangent drawn to the curve through the origin will run to infinity. In Fig. 6 the dotted line shows the curve as previously given (Fig. 1), and the solid line the suggested amended form. According to the amended curve the solution to condition (3) is now 7.4 instead of 6.4 as given by Fig. 1.

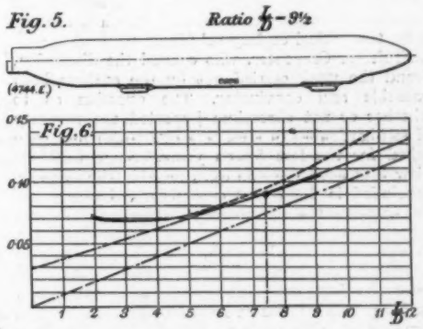
There are many factors in practice which have to be taken into account besides the general conditions on which the foregoing discussion is founded. Thus, in a dirigible, if the question of envelope weight be taken into account, the best solution will not be exactly that given by the present argument. In every individual case of design there are always some circumstances or conditions which tend to modify the broad results.











* In which the same design of form is adopted, but with a differing ratio between the longitudinal and radial scales.

* From the author's "Aerodynamics."

THE IRON AND STEEL INSTITUTE.

(*Concluded from Page* 443.)

IN our last issue we reported the proceedings on Thursday, the 4th inst., and the early part of the proceedings on Friday, the 5th.

INITIAL TEMPERATURE AND CRITICAL COOLING VELOCITIES OF A CHROMIUM STEEL.

The second paper taken at the meeting on Friday was the one bearing the above title, contributed by Professor C. A. Edwards, D.Sc., assisted by Mr. J. N. Greenwood and Mr. H. Kikkawa. It was read in abstract by Professor Edwards

and it detailed researches which confirmed the contention that chromium imparts the property of self-hardening to steel, the property of self-hardening being governed by the rate of cooling. The critical cooling velocities which produced hardening varied with the initial temperature, being much slower as the temperature was raised. The extent of this variation had been determined for a wide range of temperature. The appearance of self-hardening coincided with the presence of large quantities of martensite, and a diminution in the magnitude of the carbide thermal change. The maximum hardness was obtained when the thermal transformation had been entirely prevented, and when this was accomplished the steel was purely martensitic in structure. Whilst, with the chromium steel which had been used, the cooling rates which produced hardening were extremely slow as compared with those which were obtained in the hardening of carbon steels by quenching, the two operations were fundamentally the same. In other words, a given rate of cooling which might be regarded as slow for carbon steels really constituted quenching in the case of some special alloy steels. The precise cause of an increased initial temperature making the self-hardening more evident was not known with any certainty. The view which the authors provisionally held at present was that the chromium carbide (Cr_3C_2), which has been isolated by Professors Arnold and Read, first went into solution as $(Cr_3C_2)_2$—*i.e.*, Cr_6C_4—and was then progressively dissociated into Cr_3C_2 as the temperature was raised. When the steel was again cooling these molecules only slowly reassociated, and thus the molecular effect of the dissolved chromium carbide was greater as the initial temperature and molecular dissociation increased. This increased number of molecules in solution then enabled the carbide point to be more readily suppressed.

The authors announced that they had further researches in progress; also that they intended to extend their investigations and to determine the influence of varying carbon and chromium content upon the critical cooling velocity.

Professor Carpenter, who opened the discussion, found the work carried out by the authors both valuable and convincing. The question as to whether or not chromium imparted the property of self-hardening to steel was one which had been asked for the last fifteen years. Some held the view that such was the case, and he (the speaker) concluded in 1905 that chromium did not retard but hastened the conversion of hardening to annealing carbon, and that view was endorsed by Dr. Edwards himself in 1908. The paper was an interesting one in showing that controversies arose from the fact that information was inadequate. In his research made in 1905 he (the speaker) had found that the cooling-curve experiments for a steel containing 0.54 per cent. carbon and 1.12 per cent. chromium in cooling down from 918, 1127 and 1250 deg. Cent., the change-point was respectively at 729, 728 and 709 deg.; for a steel with 0.27 per cent. carbon and 3.24 per cent. chromium, cooled down from 910, 1000 and 1250 deg., the change-point was respectively at 738, 736 and 721 deg.; whilst for a steel having 1.09 per cent. carbon and 9.55 per cent. chromium, cooled down from 900 and 1230 deg., the change-point was respectively at 776 and 750 deg. He concluded from these figures that the chromium tended to raise the carbon change-points, and he did not think Dr. Edwards's researches damaged those facts. On the other hand, his (the speaker's) cooling velocity was 40 minutes, whilst the slowest rate of the authors was 23 minutes, and it was clear that in the earlier experiments the rate of cooling was too low to bring out the properties of the chromium steels. The authors had shown that their particular chromium steels were sensitive in regard to the cooling rates. There was perhaps a certain discrepancy between the authors' contention that chromium imparted the property of self-hardening to steel if this were placed side by side with their other conclusion where they stated that a given rate of cooling which might be regarded as slow for carbon steels, really constituted quenching in the case of some special alloy steels. He (the speaker) added at this point that something must be the matter with self-hardening, and he approached the Secretary with a view to find out who it was who first used the term "self-hardening." The Secretary, after looking into the matter, found as far as he could trace that it was first used at a meeting of the American Society of Civil Engineers held in 1892, when Professor John W. Langley, in a discussion on structural steel, qualified the metal as "a steel not requiring to be rapidly cooled in order to become file-hard." The definition of "self-hardening," therefore, was not due to a metallurgist, but to an engineer. He (the speaker) endorsed Dr. Edwards's conclusions, and asked him how he had treated his chromium steels after the heat treatment and before he performed the hardness tests. What was also the surface oxidation? The authors had rightly enforced one point, to the effect that chromium steel was a remarkable instance of a material whose hardness could be secured within narrow limits. Their showing also that with the complete suppression of the critical point the structure of the steel was quite martensitic was most interesting. Two years ago both he and the author had contributed a paper to the Institute, in which they stated that there was no constitutional difference between austenite and martensite, the apparent difference being due to twinning, and he thought their view in that respect was strengthened; the difference was physical, and not physico-chemical.

Professor Arnold, who followed, said he found the paper of very great interest. He (the speaker) was now conducting researches from which he would obtain valuable information on double carbides. He asked whether the authors meant the term "self-hardening" to refer to the steel under the Brinell test or in the lathe. If it applied to both, he would regret having spent money in equipping a lathe. Self-hardening should refer to cutting. He promised to give a brief history of self-hardening and high-speed steels. In regard to the addition of cobalt, to which allusion had been made in the course of the proceedings, his experiments had shown that 4 per cent. of cobalt added to the best high-speed steel "gave nothing."

Dr. Stead stated that the researches carried out by the authors clearly showed that science was leading to developments in every-day practice. In regard to self-hardening, the process was intimately associated with normalising. It was, however, difficult to see what occurred, for in the instance of a 1 per cent. carbon steel, rolled down from a bar to a fine wire which was normalised, some wire was obtained very hard and some soft; the difference was due to the velocity of cooling. Therefore, when normalising was referred to, the time taken should be given. Velocity of cooling was a most important factor in the case of chromium steels. Steel cooled in wire form was in the trade called "patenting;" rapid cooling left the material better and stronger. The French called it "negative quenching," and it was a most important process in the case of carbon steel. He (the speaker) mentioned the process of quenching rail-heads immediately they were rolled, and allowing the heat from the other part of the rail to let down the hardness of the head, a process which he patented. This was found too drastic, the rail-heads cracked, and he abandoned the patent. But the principle, he added, was there. A similar process was now applied to rails and tyres, but water was not used for quenching (he, the speaker, had used water), but chilling by an air blast or with steam. Many tramway rails had been so treated by this, the Sandberg process, which, it was found, increased the life of the rails by 100 and 150 per cent. He repeated that the velocity of the cooling was of very great importance in the case of plain carbon steels.

Sir Robert Hadfield said it was not the case that a mechanical engineer had introduced the term "self-hardening," for he himself had used the term in 1887, therefore before the date of the American reference which had been stated. He had understood one of the speakers to say that chromium hardened iron. He (Sir Robert) had stated in his paper on "Alloys of Iron and Chromium," contributed to the Institute in 1892, that a 0.75 per cent. carbon steel would harden energetically in water; it seemed, therefore, that chromium acted as a sort of spur to the carbon, or favoured the formation of the hardening form of carbide of iron, and even without the intervention of the ordinary cooling medium—water; he had further added that chromium *per se* did not appreciably harden iron, and he saw no reason to withdraw that statement. He still maintained what he advanced in 1892, to the effect that so far no element added to iron, in the absence of carbon, would confer scleroscopic hardness to it. That fact had always made him a carbonist, for as soon as carbon was set aside hardness could not be obtained.

Dr. Rosenhain, who followed, said he desired to say a few words of appreciation of Professor Edwards's new departure in work connected with the quantitative measurement of rates of cooling, and their influence on critical points. But one or two difficult points arose which rendered it necessary to be cautious in accepting the somewhat sweeping conclusions the author had based upon them. For instance, he reminded Professor Edwards that the specimens of steel whose cooling he was studying were in a condition in which the difference of temperature between the exterior and interior must have been very great indeed, over 100 deg. Cent. in some cases. Therefore, even if a small evolution of heat had occurred, he doubted whether it would have been possible for Professor Edwards's apparatus or any other apparatus to have recorded it. Further, the actual size of the peak on the curve representing a given evolution of heat was inversely proportional to the rate of cooling, and that must also be very carefully borne in mind. In the next place, the galvanometer of the apparatus must be moving at a considerable rate, and therefore possessed momentum which would lead it to overshoot its proper position if working at that high speed. Those were all possible sources of error which required consideration before the author's conclusions were adopted. Professor Carpenter had already justified his apprehension that the results contained in the paper were going to be used for speculation on the nature of martensite. That must be done with care, behause he thought the theory of Professors Carpenter and Edwards as to the nature of martensite was that it was an effect of strain during quenching, resulting in twinning. The paper contained evidence that that was not the case, since it contained particulars of martensite produced by a rate of cooling which could only produce very small fractions of the kind of internal stresses which occurred when the quenching was carried out for only five seconds instead of two minutes. If the steel at 1000 deg. was quenched in water, he did not think there was any doubt it would be practically entirely austenitic. He would like to know whether the steel was martensitic or austenitic under those conditions. [Here Professor Edwards said it was martensitic, and Dr. Rosenhain replied that he would like to see evidence for it.]

Professor Edwards, replying to the discussion, said that most of the remarks that had been made were of a general character, and could not be construed as criticisms. The only points to which he wished to refer were those mentioned by Dr. Rosenhain. In answer to the question he raised, that it would be very difficult, under the conditions of cooling set out in the paper, to detect a small evolution of heat if it occurred, he could only refer to some of the curves and compare them one with another. If Dr. Rosenhain thought that with the rate of cooling adopted—namely, one minute—there might be obtained a small evolution of heat at a low temperature, which would not be detected under the conditions of the experiment, he admitted the possibility. He did not think, however, that that point really could be raised as a criticism, when no evidence could be obtained of any such critical temperature on cooling from 900 deg. Cent. down to the ordinary temperature in over two hours, bearing in mind that in the case shown in one diagram (Fig. 6), from 836 deg. Cent. down to 546 deg. Cent., the time was eleven minutes. That was relatively slow, and from 546 deg. Cent. down to the ordinary temperature the time was much slower. With regard to strain in connection with quenching, he maintained what he said in the paper, and would develop it in reply to some of the earlier parts of the discussion relating to self-hardening. "Self-hardening" was a term which was purely

qualitative, and so was "quenching." The term "quenching" was usually associated with an actual plunging in water. At any rate, that was how he looked at it, although other people might view it in a different way. The same physical effect might be obtained under different conditions if the velocity of a change was being retarded with a slower rate of cooling. In other words, with carbon steels the velocity of the thermal transformation (he was not speaking of cooling velocities) was so exceedingly quick that it was necessary to adopt actual quenching in water; but with another steel, such as chromium steel, the influence of the chromium was to retard the velocity of that change. Therefore, with less quick cooling the same effect physically and mechanically could be obtained.

On the motion of the Chairman, the authors were heartily thanked for their contribution.

The last paper taken at the same meeting was one entitled :—

SURFACE-TENSION EFFECTS IN THE INTER-CRYSTALLINE CEMENT IN METALS AND THE ELASTIC LIMIT,

by Mr. F. C. Thompson, M.Met., B.Sc. It was read in abstract by the author. We commence the reproduction of this paper on page 472 of this issue. In it the idea previously put forward by several workers that surface-tension forces act within the amorphous modification between the crystalline grains in a metal was adopted and utilised to give a measure of the elastic limit. The theory afforded an explanation of the elastic limit, yield-point, and the chief effects of strain, both static and dynamic, on metals. By the aid of the relationship $E = \frac{2T}{d}$, where E was the elastic limit and T the surface tension of the non-crystalline material, a measure of the thickness of the films d in several metals could be obtained. The loss of strength of a metal such as copper (free from the complicating influence of allotropy) as the temperature was raised received a ready explanation in terms of the theory. The increased elastic limit of alloy steels, compared with a plain carbon steel, and of steel with a fine structure compared with the corresponding coarser material, was in accord with the theory's demands. The change of strength of steel with the carbon content could be foretold, and was in accord also with practical observation. The conditions governing the tensile strength or hardness of a material and its elastic limit, though running parallel, were yet distinct. The hardness and maximum stress were due chiefly to the composition of the crystalline part, the elastic limit depending on the inter-crystalline boundaries.

Professor Arnold, who opened the discussion, said the paper was one of most fundamental importance. The view frequently taken by engineers, that the elastic limit was about half the maximum stress, was a hopeless one. The elastic limit of mild steel was often zero. He was glad when the author took up that work, and he had not influenced his views in any way. He was sure the theory the author had advanced would have to receive consideration and had come to stay. It was a fact that a steel showing a breaking stress of 28 tons per sq. in. and an elastic limit of zero could be radically modified by normalising; the author explained the occurrence by stating that the crystals came in for the stress, whilst the elastic limit was dependent upon the boundaries. The author had made a remarkable specimen of iron, containing carbon 0.049 per cent., sulphur 0.02 per cent., phosphorus 0.016 per cent., which to an ordinary mind would be considered a pure iron, yet the carbon as carbides, sulphur as sulphides, and phosphorus as phosphides would give about 1 per cent. of impurities. The question of amorphous cement was a vexed one. The compounds or impurities referred to would be thrown to the edge, and he asked whether the amorphous compounds were those thrown to the edge. He (the speaker) had never handled pure iron; his nearest approach to pure metal was in the case of a gold specimen. Of this he had cast a bar, in which the crystals were large and the amorphous film was pure gold in an amorphous state. He thought that the closest attention should be given to Mr. Thompson's paper.

Dr. Rosenhain welcomed the paper as a most interesting contribution to the theory of inter-cohesion of crystals in metals, and particularly to the properties and behaviour of the hypothetical amorphous cement between crystals; this had formed the basis of speculations for which he and his collaborators had the right to claim the origin. Professor Arnold had raised the general question as to the nature and existence of the amorphous films. A review on this point would take too much time, but he (the speaker) desired to refer to one point, because Professor Arnold had spoken of pure metals. Mr. Ewen, who lost his life in France in the service of his country, and he (the speaker) had read a paper on the subject before the Institute of Metals in 1913. In that paper mechanical experiments bearing on the question of the amorphous cement were made on gold of the highest degree of purity that had ever been obtained. He did not remember what the degree of impurity was, but he thought it ran to something in the order of one in a million. That was re-melted quickly under carefully controlled conditions, so as to avoid all but the most limited contact with gases or with substances capable of contaminating the material. Experiments were also made with the purest possible zinc, which could now be obtained to a very high degree of purity, something in the order of 99.98, and also with an exceptionally pure sample of silver prepared by the electrolytic method at the National Physical Laboratory, which produced a material of extraordinarily high purity; he had not succeeded in finding in it any impurity whatever. With those three materials experiments were made which clearly showed the remarkable change of property, particularly in regard to structure, between the metal at the ordinary temperature and the metal when raised to a temperature in the vicinity of the melting-point. In the vicinity of the melting-point the crystals could be pulled apart without undergoing any deformation. They could be pulled apart with a perfectly brittle inter-crystalline structure 5 deg. or 10 deg. below the melting-point; at the ordinary temperature they broke in a ductile manner. He had quoted this merely to show that in the question of extremely pure metals experimental investigation had been made, and had given results which strongly supported the general view. With regard to Mr. Thompson's introduction of the idea of surface tension as the vital and fundamental property of the films, that was a fascinating idea. He had carefully considered it long ago, and had rejected it as being too full of additional and unnecessary hypotheses. The author said that if one relied upon the strength of the material alone, it was necessary to postulate a strength of the order of 1000 tons per square inch. He (the speaker) challenged that statement. He did not think there was the slightest foundation for it. What did investigators assume about the films? It was simply that they were stronger per unit of area than the crystalline material. That was all that need be assumed. Taking a crystalline aggregate and breaking it, it would be found that the fracture occurred, as it would do on a shock, across the crystals instead of following the boundaries. Here the speaker drew a crystal structure on the blackboard, on which he marked a line of fracture across two neighbouring crystals. There was no need to talk about thousands of tons per square inch and other figures when it was necessary to explain a matter of that kind. What apparently had led the author to look to surface tension for an explanation was the idea that the tensile strength of the films had to be assumed. That was not at all necessary, and he would be glad to know on what he (the author) based that idea. He could see no line of argument which would lead to that conclusion. With regard to the extreme thinness of the film, the so-called measurements—he (the speaker) would call them "speculative calculations"—contained in the paper were very interesting; but, after all, they depended upon a theoretical extension of formulæ which were known to apply to gases, and which had been extended to liquids, and in a still more hypothetical manner to solids. He did not think those figures could be taken into consideration until there was some experimental evidence of the thickness of the films, if they existed. There was very little evidence yet, but what evidence there was pointed to the idea that they were enormously thicker than would be imagined. His (the speaker's) difficulty about the theory at the present moment was in admitting that the films could be as thick as experimental evidence suggested they were. He was hoping, as soon as better conditions returned, to undertake an actual measurement which, he thought, would settle the question definitely. Until some measurement was available, he thought the figures for thinness given for the films were very speculative. He was aware that the author only put them forward in that way. In regard to the dependence of the elastic limit on crystal size, he had no hesitation in accepting that and confirming it from his own experience. It was a fact long known to those who had to deal with steel and other metals that the first sign of wrong treatment, particularly of undue heating, was a depression of the elastic limit.

Dr. Stead found the paper an extremely able one, which had necessitated a very great amount of research work. The man who was too frightened to advance a new theory was a coward. The author had put one forward—he admitted it was a tentative one—but it appeared to be justifiable. He (the speaker) wanted still further data in connection with boundaries. Professor Howe had stated that the cement or amorphous theory was one which had for ever to remain outside the limits of research. Dr. Rosenhain had said that those films were not ultra-microscopic, and what he (Dr. Rosenhain) had also said in regard to metals breaking across the crystals had an important bearing upon the matter. Lead broke up in the same way, tin also, both pure and impure. There was something between the crystals that was not understood, and the author's paper would be useful to throw light on the point. It had been shown by Mr. Aitchison that the amorphous substance was more soluble in acid solutions than the crystals, and this explained the effect of etching in throwing up the texture. On etching, the grooves round the crystals did not indicate the film thickness; there might be gases at the boundaries also. Dr. Stead here gave the author a specimen of steel which by constant use under a press had become very brittle, and on heating it below the melting-point of zinc its strength had increased, whilst after heating it above the critical point it had returned to its pristine hardness.

Professor Turner, who followed, said he had felt for many years that further research, from the point of view of mathematico-physics, should be carried out, and he welcomed the paper. Two films were to be considered when speaking of surface films, one round the crystal grain, which would be more or less thin, whilst if the step plane inside the crystal were considered this would probably be very thin. There was a very large number of films, side by side, of very great thinness. He showed on the blackboard how a fragment of crystal could be torn asunder and be in tension, being left in a strained condition. Was that a theory or a fact? If it were a fact, there would be a difference in density, a lighter because of the strained condition, and a heavier when annealing had taken place. By wire-drawing metal decreased in density, and increased again when annealed. When pressed steel decreased in density, a large number of shearing planes were formed, every one being in tension. It had been shown that the surface tension could vary, according to the class of metal, from two to seven times the strength of the metal originally. The subject should be studied from the point of view of the effect of wire-drawing and annealing.

Dr. Hatfield was grateful to the author for his contribution. He (the speaker) always admired Dr. Rosenhain's nimbleness of imagination; but the question was a purely theoretical one, and it should be dealt with as such. It was too early to dogmatise upon it. He compared the author's statement to the effect that the number of metals, the thickness of the inter-crystalline films of which had been measured, was too small to draw any conclusion, with another of his statements where he said that the only essential difference between the three samples considered lay in the crystalline size. This latter statement was perhaps too definite, and the author might be going too far. No one could state that the difference was in the crystalline size. Dr. Stead had said that Professor Howe's contention was that

A PRACTICAL APPLICATION OF OPTICAL STRESS ANALYSIS.

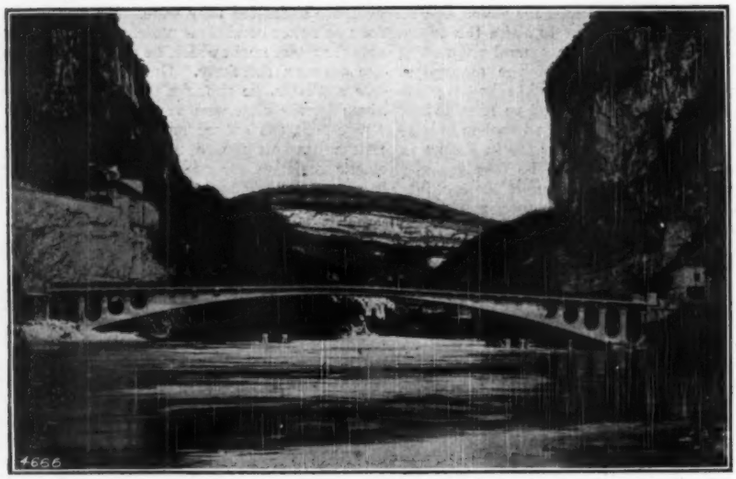


Fig. 1.

Fig. 2.

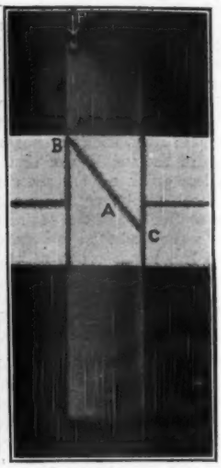
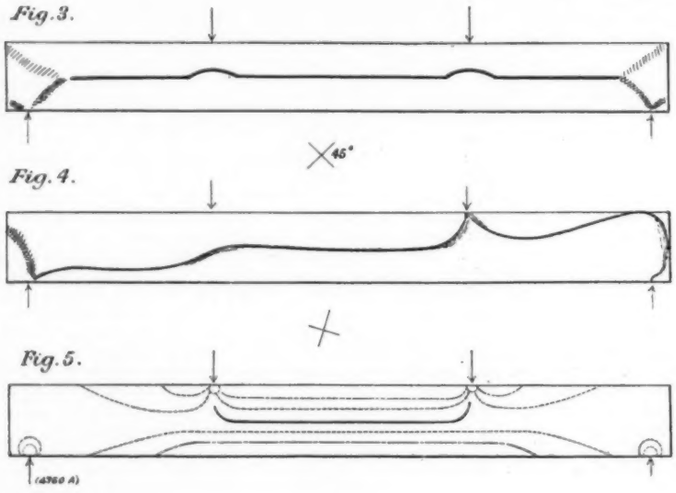
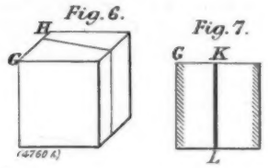


Fig. 8.





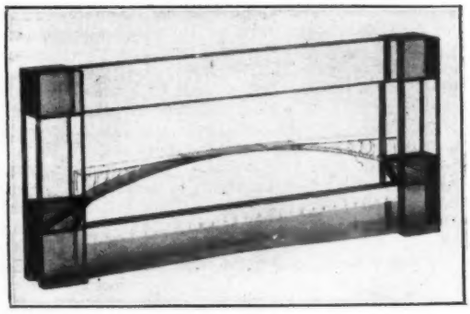


Fig. 9.

the amorphous theory would remain a theory. He (the speaker) added, with reference to this, that a number of the members had been, on the foregoing evening, to the lecture delivered by Professor W. H. Bragg on X-Rays and Crystal Structures, where they had gathered that our ignorance of crystalline structures was very great, and although the work in that field was most entertaining, it would be desirable to wait before giving form to our ideas. Professor Bragg's lecture would have for effect to advance our knowledge, and he hoped the Professor would extend his work to the metallography of ferrous metals.

On the motion of the Chairman, who stated that the author would reply to the discussion by correspondence, Mr. Thompson was awarded the thanks of the meeting for his very valuable paper.

The three remaining papers on the list were taken as read. These were the following:—"A New Thermo-Electric Method of Studying Allotropic Changes in Iron or other Metals," by Dr. C. Benedicks; "Early Experiments on the Recalescence of Iron and Steel," by A. Mallock, F.R.S.; and "Experiments on the Hardness-Testing of Mild Steel," by W. N. Thomas, B.Sc.

The usual votes of thanks, to the Institution of Civil Engineers for the loan of their hall, and to the Chairman, concluded the proceedings.

A PRACTICAL APPLICATION OF OPTICAL STRESS ANALYSIS.

The constantly extending use of reinforced concrete is compelling engineers to consider some exceedingly complicated problems in elasticity, owing to the fact that with this material the joints and connections between the different parts of a structure are almost invariably of very great rigidity. It is, in fact, generally considered advisable to make the work as monolithic as possible. Of course, so far as considerations of safety are concerned, it is usually quite permissible to neglect the stiffness of the joints, since the uncalculated secondary stresses which may then exist are never dangerous. At the worst a joint may crack and open, but this will merely reduce the actual condition of the structure to a closer agreement with what was assumed as a basis for calculation.

The drawbacks to this procedure are two. In the first place, it becomes difficult to compare one structure with another of somewhat different design, since the calculated stresses in the two cases may not bear the same proportion to the actual stresses. It may accordingly be illegitimate to assume that because the one structure, built to a certain calculated stress, has proved satisfactory, that an entirely different type of structure built to the same calculated stress will also be satisfactory. In the second place, by making due allowance for the stiffness of the joints and for the flange effect of the roadway, a very considerable saving in material may be effected. This, as M. Rabut has most strikingly shown, is true even in the case of metallic bridges, and the consideration applies with even more force to structures of reinforced concrete.

Consider, for example, such a bridge as that illustrated in Fig. 1, which represents a reinforced-concrete bridge of 95 metres span built across the Rhone at Balme. Here it is obvious that the effect of the roadway is greatly to enhance the strength of the arch, but it is by no means a simple matter to compute just what this effect is worth.

The complete solution of the problem by the method of least work is no doubt theoretically feasible to a high degree of precision, but the arithmetic involved would be of the most appalling character. In the present case the designer, M. Rabut, turned the difficulty by assuming the structure as a whole, roadway and arch ring included, to form a single arched rib with a centre line intermediate between the upper surface of the roadway and the intrados of the arch.

A PRACTICAL APPLICATION OF OPTICAL STRESS ANALYSIS.

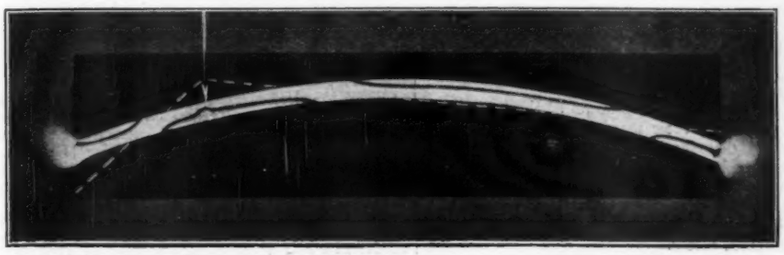


FIG. 10.

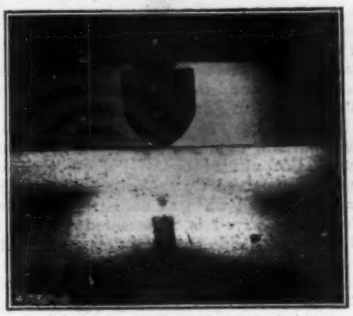


FIG. 12.

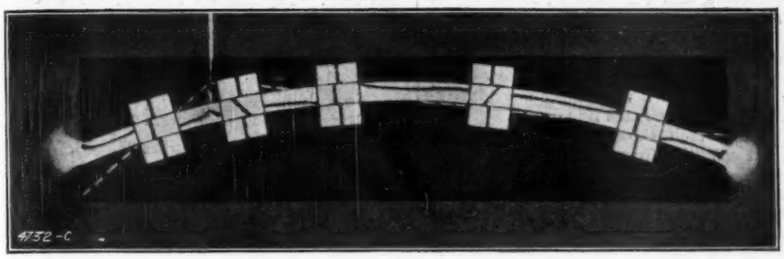


FIG. 11.

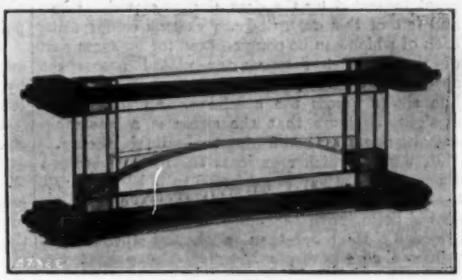


FIG. 13.

Much judgment is, however, needed to locate this centre line satisfactorily. In the end it was decided to check the results thus obtained by making a glass model of the structure, and determining the stresses in it by means of polarised light. This work was carried out by M. Mesnager, who has described his methods in *Annales des Pont et Chaussees*, Fasc. iv., 1913, to which we are indebted for much of what follows.

When a beam of plane polarised light is passed through a homogeneous transparent medium, it is quite unaffected, issuing from it as it entered, and remaining still a beam of plane polarised light, which can be quenched by a nicol prism appropriately adjusted. If, now, the transparent material be strained, rendering it no longer homogeneous, it does affect a beam of plane polarised light, which in general it breaks up into two beams of light polarised at right angles to each other, and the new planes of polarisation may make any angle whatever with the original plane. Hence a nicol, set so as to quench the light when the transparent material was unstrained, is, in general, unable to do so when the original homogeneity of the material is destroyed by straining it. There are, however, two exceptional cases. If a principal axis of the strain coincides with or is at right angles to the original plane of polarisation, the light is unaffected by passing through the material, and is accordingly quenched by the nicol just as before.

Fig. 2 represents a glass strut subjected to an eccentric load. In this case the plane of polarisation of the light was parallel to the direction of the stress, and the consequence is that most of the body of the strut, as viewed through the nicol prism, remains as dark as it was before the stress was applied. This shows that throughout most of the body of the specimen the stress is parallel to the axis. It will be seen, however, that just in the neighbourhood of the point of application of the load light has managed to get through. This is due to the fact that there is always a complicated distribution of stress in the immediate neighbourhood of the point at which a load is applied. This complication, however, rapidly dies away, disappearing, it will be seen, within a distance not greater than the width of the specimen. Hence, throughout the body of the specimen as a whole the stress is wholly parallel to the axis. This is, of course, the usual assumption.

Since a strained specimen remains dark at every point in which the direction of either of the principal stresses is parallel to the plane of polarisation, it is possible to map out the direction of these stresses for every point of the specimen. The whole series of stress lines can therefore be plotted as has already been explained by Professor Coker in ENGINEERING, vol. xci., page 1.

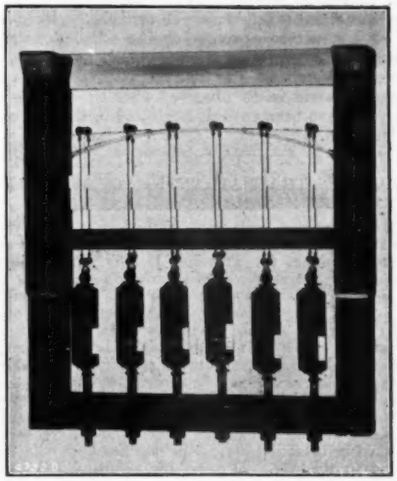


FIG. 14.

Fig. 3 represents, according to M. Mesnager, the appearance observed when a beam loaded symmetrically with two loads is examined with light polarised at an angle of 45 deg. with the axis of the beam. In this case there is no shear in the central section of the beam, and no stress whatever along the neutral axis there, and we get accordingly the dark line shown. The humps underneath the arrows are due to the local effects of the applied loads, which, it will be seen, rapidly die away as the distance from the loads increases. If the stress be sufficient, colour effects are obtained as well as the dark line.

In the end section of the beam the neutral axis is subject to shear and to no other stress. This shear is, of course, equivalent to a tension and a compression at right angles to one another, and both inclined at 45 deg. to the neutral axis. Hence, with the nicols set at 45 deg., the direction of the principal stresses will be parallel or perpendicular to the plane of polarisation, so that this axis should appear as a dark line, and this, it will be seen, is the case. When the nicols are set at 30 deg. and 60 deg. to the axis of the beam, on the other hand, the line that shows dark has the shape indicated in Fig. 4. Everywhere along this line the principal stresses make angles of 30 deg. and 60 deg. respectively with the axis of the beam.

Circularly polarised light may also be used for stress analysis. This kind of light is obtained by passing a beam of polarised light through a quarter wave plate. In plane polarised light the motion of the vibrating particle is along a straight line. The quarter wave plate transforms this path into a circle. When this circularly polarised light traverses a strained transparent plate, this circular path of the vibrating particle is distorted into an ellipse, which by the passage through a second quarter wave plate is transformed back into plane polarised light again. If the light received by this second wave plate is circularly polarised, one beam only of plane polarised light is produced; but when the circle has been transformed into an ellipse by passing through a strained section of the plate, two rays are formed, polarised at right angles to each other. These, on traversing the second nicol, each contribute a portion to the light that finally gets through. As these two portions have passed through paths of different lengths, optically speaking, they interfere, producing the colour effects already described in ENGINEERING. The colour observed at any point of the specimen depends on the difference between the greatest and least stress at that point. If these two principal stresses are equal, there is no colour and the point remains dark.

Fig. 5 represents, according to M. Mesnager, the appearance of the beam already referred to when viewed by circularly polarised light. There is no stress whatever along the centre line of the mid-length of the beam, and we get, accordingly, the dark line shown. The broken lines indicate the shape of the different colour bands observed. As stated, the colour depends on the difference between the principal stresses. In very many cases—as, for example, at the boundary of a specimen—one of these stresses is known to be zero, so that the actual stress on the specimen can be ascertained by straining a small bar of the same material until it matches the colour at the point under investigation. This plan has been followed with great success by Professor Coker.

Another method has, however, been used by M. Mesnager, who employs a Babinet compensator. This consists of a double prism of quartz, such as

indicated in Fig. 6. The two components when placed together form a parallel plate, but the crystal axis of the one component is perpendicular to that of the other. If polarised light be passed through this plate, we get a dark line, H L (Fig. 7), at the point where each component has the same thickness, and from this line varying colour tints extend right and left to the edges of the prism. The colour is the same at equal distances from the centre line H.

These tints will each compensate for the complementary tint yielded by a strained specimen examined with circularly polarised light. The appearance observed when an eccentrically loaded strut is thus observed is represented in Fig. 8. As will be seen, outside the region covered by the compensator, the specimen shows a dark vertical line, which indicates the position in which the axial stress is zero. The load being applied outside the middle third of the cross-section, the right-hand edge of the strut is in tension, and there is a neutral point indicated by the dark line as stated. Right and left of this dark line are various colour tints, each of which can be compensated for by some part of the Babinet compensator placed across the specimen as indicated. As a result a dark diagonal line shows across the specimen. As this line is straight, it shows that the stress is a uniformly varying one, thus confirming the ordinary theory.

In Fig. 9, which represents the results obtained when a notched bar is subjected to a bending test, the position of the neutral axis is shown by the dark spot a little above the notch. This being nearer the edge of the notch than to the top of the beam, proves that the stress is much higher near the notch than on the upper surface of the bar.

The Babinet compensator can be graduated to show in kilogrammes per square centimetre the stress on a standard sheet of glass, which will be compensated for at different distances from the centre line of the instrument. In another form the two components of the compensator are arranged to slide one over the other by means of a micrometer screw. The relative contribution of the two components to the total thickness of the prism, opposite to a fiducial line, can thus be varied, and the screw graduated to show the stress compensated at this line with different settings.

A small arched rib of glass, loaded with an isolated load, is represented in Fig. 10 as observed by circularly polarised light. The dark line represents everywhere the unstrained layer of the rib. At the sections where this line reaches the boundary of the rib, the line of thrust on the arch passes through one or other of the limits to the middle third.

In Fig. 11 is shown the same arch photographed, along with a number of Babinet compensators. Where the dark line at the compensator is normal to the rib the thrust is also normal, and there is no shear on the sections. Elsewhere, it will be seen, the compensators indicate that the stress is a uniformly varying one, which is in accord with the usual theory, when the depth of the rib is small compared with its radius of curvature.

This experiment had reference, of course, to the relatively simple case of an arched rib of uniform moments of inertia *encastré* at the ends. The calculation in such cases is fairly simple, and the experiment is, perhaps, interesting rather than instructive. When, however, we come to such a case as that of the arch represented in Fig. 1, some very sweeping assumptions have to be made in order to make the structure reasonably amenable to mathematical treatment. It was, therefore, considered desirable to confirm experimentally the conclusions arrived at in this way. An attempt to measure by mechanical means the stresses in a model proved unsatisfactory, and M. Mesnager was requested, accordingly, to investigate the stresses by optical methods. The bridge in question is of 95 metres span, and is, it will be seen, a very bold structure.

The glass model was cemented to a framework of glass, as indicated in Fig. 12. The cement used was apparently some form of what is known in this country as fish glue. It was found of prime importance to make all these cemented joints between faces perpendicular to the direction of the light used in the subsequent optical analysis of the stresses. Unless this were done the shrinkage of the glue in drying gave rise to local strains, which complicated the interpretation of the experiments. This glass model and frame were mounted on a wooden frame, as shown in Fig. 14, and the load applied as indicated by means of carefully calibrated spring-balances. The stresses to be anticipated from changes of temperature were also determined by varying the span of the arch by definite amounts by means of the compression rods shown in Fig. 13.

The stresses being a maximum at the boundaries of the structure, their maximum values could be determined directly by means of polarised light. At every free boundary, in fact, one of the principal stresses is zero, so that the difference between the principal stresses, which is what can be determined by optical methods, is in such regions the same as the maximum stress.

The measurements were made by means of the micrometer compensator already referred to, at twelve sections, both on the intrados and extrados of the structure, and with isolated loads, applied either singly or in combination at six different points of the roadway.

An important point established by this investigation was that owing to the assistance afforded by the roadway there was, under any load, no tension whatever on the arch ring proper.

The general result showed that the calculated stresses did not differ from the true by more than 14.7 per cent. as a maximum. This figure is, M. Mesnager states, less than the discrepancies generally observed in the case of ordinary metallic bridges, in which, for example, it is usual to neglect the effect of the roadway, which really acts as so much additional flange material, and also the stiffness of the joints. It is, he states, seldom that the difference between the calculated stresses and the actual stress falls below 25 per cent. in the case of such structures, even when the calculations are made as carefully and completely as possible. Indeed, discrepancies as high as 100 per cent. have been in some cases observed when the secondary stresses have been entirely neglected in the original calculation.

FRENCH TRANSATLANTIC QUADRUPLE-SCREW STEAMSHIP "LAFAYETTE."

ON the morrow, as it were, of the loss of one of the finest steamships belonging to the Compagnie Générale Transatlantique, the Provence II. (its numeral distinguishing it from the large French cruiser Provence), it is of particular interest to show that in the matter of activity in new construction the company has not been materially affected by the war. In proof of this it may be stated that the company has in course of construction, on the stocks at St. Nazaire, a steamship with scantlings considerably superior to those of the France,* to which we referred in describing the works of the Chantier et Ateliers de St. Nazaire. Originally it was anticipated that this vessel would have been finished in 1914, but her completion has been delayed owing to the war. Further, the company has just completed and put into service a new steamship bearing the name Lafayette, and although this vessel has not the dimensions of the Provence, still less those of the France or of the vessel on the stocks at St. Nazaire, it represents, nevertheless, a very fine unit, and derives additional interest from the circumstance that it has been finished in spite of the war.

The hull of the Lafayette was built at the Port de Bouc yard, on the Mediterranean, at the entrance of the Etang de Berre, where the new Marseilles-Rhone Canal† passes. This yard is the property of the Société Anonyme des Chantiers et Ateliers de Provence, who in normal times are very actively engaged. The engines of the vessel were constructed partly at the Ateliers de la Madrague (also in the neighbourhood of Marseilles), belonging to the Société Anonyme des Chantiers et Ateliers de Provence, and partly at the Chantier de Penhoet, the property of the Société Anonyme des Chantier et Ateliers de St. Nazaire, the builders of the large transatlantic liner above referred to, which, it is expected, will be finished in a few months. The Lafayette was successfully launched on May 31, 1914, and has been in service on the New York line since October 30 last.

The principal dimensions of the ship are as follow :—

	metres.	ft.	in.
Length over all	171.83	563	9
Upper deck length	159.53	523	5
Length between perpendiculars	164.38	539	3
Extreme breadth	19.53	64	0
Depth, moulded	14.17	46	6
Mean draught	7.400	24	3
Tonnage :—	tons		
Gross	11,952.97		
Net	5,908.05		
Displacement at above draught	14,800		
Gross burthen at above draught	5,200		

The Lafayette is illustrated in the view, Fig. 1, on Plate XL., on which also are reproduced, in Figs. 2 to 5, plans of the deck-houses, bridge, astern platform and shelter-deck; on Plate XLI. are a longitudinal section of the vessel and plans of the promenade, upper, and first and second 'tween decks; whilst Figs 11 to 14, on Plate XLII., are views of the various saloons. The ship has four decks, the height between the decks varying from 2.2 m. to 2.7 m. (7 ft. 3 in. to 8 ft. 10 in.).

The total bunker capacity equals 3013 cubic metres, (106,420 cub. ft.), while the total volume of the water ballast and fore peak tanks amounts to 1196 cubic metres (263,120 gallons). The total volume of holds and cargo spaces is, including the space on the upper deck for the emigrants, 4167 cubic metres (147,000 cubic feet). The distance apart of the frames is 670 mm. forward and aft, and 730 mm. amidship (26.3 and 28.7 in.). The vessel has accommodation for passengers, &c., as follows :—

First-class	336
Second-class	110
Third-class	90
Emigrants	712

The safety equipment comprises 33 craft, including lifeboats proper, small boats, and rafts, collectively capable of carrying 1964 persons; that is, all the passengers and crew. Additional security is afforded by twelve transverse water-tight bulkheads.

The contract speed of the Lafayette is 19 knots. This is not a remarkable speed for an Atlantic liner, but it secures a fairly quick passage at moderate rates and a moderate expenditure of engine power.

In view of the moderate speed required, the machinery is of relatively limited power, the I.H.P. being 14,400, a modest figure when compared with the horse-power of a modern fast Atlantic liner.

The propelling machinery consists of two reciprocating compound engines, with four cranks. These engines exhaust into two low-pressure turbines placed in the wings, each engine and each turbine accordingly operating a separate line of shafting and one propeller. Each reciprocating engine has four cylinders—two high-pressure and two low-pressure cylinders. The diameter of each of the high-pressure cylinders is 0.680 metre (26.7), and of each low-pressure cylinder 1.220 metres (48 in.); the pistons have a common stroke of 1 metre (39.37 in.). The condenser is of the "Uniflux" type, and the boilers, which are of the marine cylindrical type, are fitted with Howden forced draught. The number of boilers is thirteen, each having a diameter of 4.560 metres (15 ft.), and a length of 3.325 metres (10 ft. 11 in.). The boilers have collectively 39 furnaces, and the total grate area is 70.72 square metres (761 sq. ft.), while the total heating surface is 3200 square metres (34,450 sq. ft.).

It will be seen from the section and plans of the vessel that most of the emigrants are accommodated forward and some aft in the lower portion of the ship; in this latter part also will be found the third-class accommodation. The second-class passengers are arranged for towards the centre of the vessel, while the first-class accommodation is placed still nearer amidship. The public rooms of the first class—the drawing-room and dining-room—are placed forward of the first funnel. On the bridge and upper decks are the captain's cabin and saloon and the officers' quarters, together with other accommodation and the wireless telegraph installations.

On the awning deck aft are situated the public saloon and the smoking-room for second-class passengers, and amidship are the state cabins, smoking-room and drawing-room of the first-class passengers, together with the children's playroom. On the promenade deck, towards the centre, there are a series of state cabins, and further aft are the semi-state rooms. Fore and aft on the upper deck are the sanitary arrangements for emigrants, and more towards the centre the dining-rooms for first-class and second-class passengers. It is upon this deck, of course, that the principal group of ordinary first-class cabins are placed. The greater part of the third-class installations are on the upper 'tween-deck, together with an important group of second-class cabins, some first-class cabins, children's first-class dining-room, and the dining-room for emigrants. Finally, on the lower 'tween-deck will be found the accommodation for all the emigrants, and the greater part of the ship's personnel and crew. Figs. 11 to 14 are views in the dining-saloon, the smoke-room, ladies saloon and lounge. The vessel appears to be well arranged, and likely to prove equal to the best in the service. The speed, as we have said, is only moderate but the ship is comfortable, a desideratum in the case of all passenger vessels.

* See ENGINEERING, vol. xc., page 850.

† See ENGINEERING, page 316 *ante*.

INDUSTRIAL NOTES.

THE Director of the Department of Labour Statistics, writing on the state of the labour market in April in the *Board of Trade Labour Gazette*, says that in that month all the principal industries were well employed, and some were working at great pressure. The increasing number of enlistments emphasised the need for more women and girls, and the substitution of them for men had to be carried much further than hitherto if the requirements of industry were to be met.

The changes reported as taking effect in April, all of which were increases, affected nearly 320,000 workpeople, and resulted in a total addition of over 30,000*l.* to the weekly wages of those concerned. The principal bodies of workpeople affected were 114,000 coal-miners in Scotland and 44,500 in Northumberland; 30,000 engineers in the Manchester district; 20,000 iron puddlers and millmen in the Midlands; 20,000 carters in London; and about 17,500 workpeople in the building and allied trades.

The number of disputes beginning in April was 55, and the total number of workpeople involved in all disputes in progress was 54,656, as compared with 58,388 in the previous month and 10,222 in April, 1915. The estimated total aggregate duration of all disputes during the month was 654,600 working days, as compared with 327,300 in March, 1916, and 67,200 in April, 1915.

The average weekly number of vacancies notified to all Labour Exchanges for the five weeks ended April 14 was 38,734, as compared with 35,337 in the previous four weeks, and with 34,418 in the five weeks ended April 16, 1915. The average weekly number of vacancies filled for the same periods was 29,507, 27,417 and 25,131 respectively.

All the Bristol Channel coal-trimmers, says the *Liverpool Journal of Commerce*, are now charging double rates for neutral vessels. Last week, Mr. Twomey, Secretary of the Amalgamated Labourers' Union, to which all the men belong, told the *Journal's* representative that the men thought they were entitled to share the great profits the neutrals were making. They were not charging the British or Allied shipping more. Regarding working on Saturday afternoons, the trimmers and tippers of the Bristol Channel ports entered into an agreement with the Port and Transit Executive Committee to work on merchant tonnage up to eight on Saturday nights, with overtime from 1 o'clock, British free tonnage paying 3s 6d. each man per hour, neutral and Allied free tonnage 5s.

The report, dated the 8th inst., issued by the Steam-Engine Makers' Society states the membership to be 20,300, with only one member temporarily unemployed. Dealing with the question of dilution of labour, the report adds that whilst this question has to be faced, it should not be considered in the light of a menace to the efficient, competent, and skilled craftsmen; it only affects those who by apprenticeship, training or service, have little or no claim to be classed as "engineers."

The latest report issued by the Boilermakers' Society states the membership now exceeds 73,000. Of this total only 153 members are temporarily unemployed. The report adds that if there were perfect co-operation between employers and men, the members now idle would be absorbed. The number of members superannuated and sick is also low, owing, no doubt, to the willingness to continue at work of men who, in normal times, would be rightly on the funds of the Society.

In an article in the *Textile Mercury* on the systematic slacker, and in regard to a passage in Sir William Beardmore's presidential address before the Iron and Steel Institute dealing with the higher output of women over that of skilled workmen, it is stated that textile employers are not strangers to the same malpractices. There are men in the works to-day who of set purpose refuse to allow machines to produce more than 55 per cent. of a nominal efficiency, when they could, with no more exertion on their own part, work at 80 per cent. There are boys who, after a week or two of honest effort, during which they have broken the speed limits, have been brought under control by the conspirators, and been obliged to reduce the output of their machines to that of dishonest men who joined the trade before them. This deliberate wasting of time and opportunity is an offence for employers to check, but it is also a sin against others than themselves. It is, in the fullest sense, a national interest that this vice should be exterminated, and that all the excuses by which its practitioners are wont to palliate the plague should be rent to pieces in public. The evils of drink and of betting, against which our reformers incessantly fulminate, are, in their purely economic effects, as nothing beside this omnipresent vice of sloth and stupidity.

When the result of the ballot of the Amalgamated Society of Engineers on the question of a political fund levy of 3d. per member per quarter was announced, says the *Glasgow Herald*, surprise was experienced by some people at the number of men who opposed the proposal. The majority was 13,520, and the minority 11,759. The details of the voting, which are now available, will probably be regarded as still more surprising, for they show that a great deal of the opposition to the levy is in the larger industrial areas. Of the Glasgow branches, for instance, 17 voted with the minority. All the Clydebank votes were adverse, so were six of the Govan votes, four of the Greenock votes, and two of the Partick votes. A conclusion drawn here from the figures is that the rank and file of the society do not care so much for the direct Parliamentary representation of labour as they are assumed to do. It would be interesting, however, to know how much of the opposition is due to workers who prefer what is called "direct action" to constitutional methods.

An increase in the wages of carpenters and joiners of several districts in the United Kingdom has recently been announced. The following are a few of the figures: Carlisle, 1½d. per hour, and 1s. per week as country allowance; Doncaster, ½d. per hour; Grimsby, ½d. per hour; Huddersfield, 1d. per hour; Oldham, ½d. per hour; Selby, 1d. per hour; Southport, 1d. per hour.

The Amalgamated Society of Engineers, during the first quarter of 1916, added 83,687*l.* to its accumulated funds, making a total of 1,454,575*l.*, of which 643,752*l.* come under superannuation reserve. This very large quarterly increase was largely due to the decrease in donation benefits. Since, further, many of the older men have temporarily returned to work, superannuation payments were also less heavy.

As announced on page 458 *ante*, the Executive of the Mining Association and that of the Miners' Federation held their joint meeting in London, on Tuesday last, to consider the advisability of adopting schemes for increasing the output of coal. The following were the proposals submitted for consideration:—

1. The further employment of women on the surface of collieries.
2. Reduction of age limit for boys.
3. Absenteeism.
4. Utilisation of the one hour per day for sixty days (Section 3 (1) of the Eight Hours Act).
5. Suspension of the Eight Hours Act.
6. Holidays.

The meeting decided unanimously as follows:—In regard to absenteeism, it agreed that the matter be referred to the districts, on the understanding that committees be at once set up in each district to devise and put in operation effective machinery to secure the attendance of all the workmen employed to the fullest extent possible; further, to inquire into the circumstances of workmen employed in the mines not being provided with work whenever they present themselves, the intention being to secure, as far as possible, the output of coal necessary for the country's needs. A resolution was also passed recommending the curtailment of holidays as far as possible.

The meeting was adjourned to June 22, to receive reports from the districts. The suspension of the Eight Hours Act, and the working of one hour extra in 60 days of the year, are to be further inquired into at this second meeting.

Sir George Croydon Marks, M.P., having been appointed by the Minister of Munitions to conduct certain important inquiries abroad on his behalf, has been obliged to relinquish his post as a Commissioner for the Dilution of Labour. The Minister has accordingly decided to extend the reference to the Commissioners for the Dilution of Labour on the Clyde so as to include the Tyne district, which was previously dealt with by Sir George Croydon Marks.

SUBMARINE TELEGRAPHY.—The past year's dividend of the Eastern Extension, Australasia, and China Telegraph Company, Limited, has been increased from 7 per cent. to 8 per cent.; the 8 per cent. is also paid free of income tax—which is something in these times—and a reliquat of 38,816*l.* is carried forward. The company's general reserve fund has been increased by 40,912*l.* in connection with the closing and disposal of the Banjoewangie and Roebuck Bay cable, owing to the establishment of improved means of communication with Australia, making it unnecessary to continue the maintenance of this cable. On the other hand, the fund has been debited with 74,686*l.* for partial cable renewals carried out in the course of the past twelve months. The company had to provide 51,312*l.* for expenses attending the maintenance of cable depôts at Singapore and Adelaide, and the company's factory at Singapore figured in this total for 12,437*l.* The cost of cable expended last year on repairs (after deducting the value of picked-up cable) was 16,236*l.*

NOTES FROM THE UNITED STATES.

PHILADELPHIA, May 3, 1916.

The past week has shown some evidences of lessened activity in certain lines. The exception is in structural material; much of the contemplated business of a few months ago is now coming to the front. Among recent large orders are one for 3000 tons for pier work in New York City and one for 4000 tons for a St. Louis hotel. The reason for present activity in structual material is that orders for material to go into construction during the last quarter of this year must be placed now or very soon. In crude iron, prices still point to a higher level. The pressure of inquiries is leading makers to quote higher. The Bethlehem Steel Company has been a heavy buyer of basic, and the Reading Company has bought 10,000 tons of forge. Jones and Laughlin have contracted for 50,000 tons of basic and 5000 tons of foundry. Every condition present and prospective favours the furnaces. Wire products have just been advanced 2 dols. a ton to 47 dols. for base size wire; galvanised and barbed wire are also higher. It is probable that the present base price of steel plate, which is 2.75, will be withdrawn, and some mills have already secured some business at 3 cents at shipyards. Car-builders and other interests are very insistent with their demand for protection against higher prices in the future. The comparative quietude in the market is mainly due to the over-sold condition of mills. Railroad earnings for March broke all previous records; extra dividends are common in railroad circles. Silver has taken a phenomenal advance and is now higher than for over 20 years, large shipments being made to China and other Oriental countries; heavy demand for lead and tin plate continue and tin has advanced, the nominal price being to day 50 cents. Continued activity is probable in all lines. European inquiries for basic iron indicate heavy transactions in the near future. It is probable that the momentum of demand will carry prices for this year's delivery somewhat higher.

STRUCTURAL STEEL.—The orders for American structural steel placed in the United States in the first quarter of this year were: January, 118,680 tons; February, 130,000 tons; and March, 186,000 tons; total 434,680 tons. The corresponding orders placed in the first quarter of 1915 were 204,000 tons, and in the first quarter of 1914, 408,000 tons.

CEMENT IN GERMANY.—The German cement industry continues to labour under unfavourable conditions, and dividends are reduced or have been discontinued. The Portland Cement Company, Saxonia, pays 3 per cent. dividend for 1915, against 4 per cent. for the previous year, and the report states that the sale was only 35 per cent. of the normal. The Alsen Portland Cement Company pays 4 per cent. for 1915, by using the balance carried forward from 1514, against 8 per cent. for the latter year. The Oppeln Portland Cement Company pays 4 per cent. for last year, against 6 per cent. for 1914.

STANDARD STEEL SPECIFICATIONS FOR AUTOMOBILE CONSTRUCTION.—It will be remembered that in December, 1914, a meeting was held by the Institution of Automobile Engineers in Birmingham, and an invitation was issued to all those interested in the manufacture of steel as far as it concerns automobile engineering. At this meeting a paper was read by Mr. L. H. Pomeroy emphasising, among other things, the need for a reduction in the number of steels then in use in automobile construction, and also for a better understanding between automobile engineers and steel-makers. The outcome of the meeting was the appointment of a Committee consisting of steel manufacturers, stampers, and automobile engineers. As a result of less than twelve months' labour this Committee has suggested a series of ten standard steel specifications for use in automobile construction, and these specifications have now been finally approved by the Engineering Standards Committee and are being issued by that body.

THE LATE MR. JOHN D. PARKER, GLASGOW.—We regret to learn of the death on the 15th inst., at his residence, Holyrood-crescent, Glasgow, of Mr. John D. Parker, at the age of 72 years. Mr. Parker was born in Beith, and received his training in the office of Mr. David Smith, civil engineer and land surveyor in Glasgow. He then entered the service of the North British Railway Company under the late Mr. James Deas, C.E. When the latter was appointed engineer to the Clyde Trust Mr. Parker went with him as assistant. While in that service he was associated with many schemes in connection with the development of the river, and in particular with the Kingston Dock and Queen's Dock. In the eighties he left the Clyde Trust and became connected with the late Sir W. R. Copland's firm, and the execution of the many important water, drainage, and other engineering undertakings carried through by them came under his special supervision. About two years after Sir W. R. Copland's death Mr. Parker was joined in business by his son, Mr. W. A. Parker, C.E., at present with the forces as Captain in the 5th Scottish Rifles, and the late Captain Peter I. Whitton, son of Mr. Whitton, Park Superintendent, Glasgow. Captain Whitton was killed in the early days of the Gallipoli campaign. During this period Mr. Parker completed the Glenquey Reservoir, and carried through the Kelso Burgh water scheme, the new tidal basin for the London and Glasgow Engineering and Shipbuilding Company, and numerous other schemes. Mr. Parker became a member of the Institution of Civil Engineers in 1886. He is survived by his wife, his son, and two daughters.

SURFACE-TENSION EFFECTS IN METALS.

*Surface-Tension Effects in the Inter-Crystalline Cement in Metals and the Elastic Limit.**

By F. C. THOMPSON, M.Met., B.Sc. (Demonstrator in Metallography in the University of Sheffield).

IN a paper read recently before the Faraday Society (1)† a new theory concerning the elastic limit was propounded. At the suggestion of Sir Robert Hadfield, to whom the author is deeply indebted for invaluable advice and highly appreciated encouragement, a revised and extended account is now placed before the Institute. No apology need be made for introducing this theoretical study in view of its immense practical importance.

During recent years very considerable attention has been paid to the intercrystalline boundaries in metals. Among the many remarkable facts which have been elicited, none is more curious than their great strength. It is a fact which could not have been foreseen that in a normal ductile metal, such as iron, fracture under tensional or torsional stress does not occur in the regions between the grains, but passes through the bodies of the crystals themselves. From whence does this unexpected strength of the boundaries arise?

An explanation of the phenomena has been sought by applying the theory of Dr. Beilby (2)—first proposed to explain the hardening of a metal by cold work—that the material between the crystals is locally amorphous, and of the nature of a drastically under-cooled liquid. Now since glasses, and other materials in a similar metastable condition, are in general distinctly harder than the corresponding *crystalline* solid, the first and most obvious explanation of the strength of the intercrystalline boundaries of a metal is that due to Dr. Rosenhain (3), which finds the cause in the strength of the cementing material itself. Accepting as a working hypothesis the existence of these amorphous films, the explanation just mentioned is in the highest degree difficult to reconcile with their obvious thinness. Certainly ultra-microscopic, there are, as will be seen later, reasons for assigning a thickness of the order of 10^{-5} or 10^{-6} centimetre. It is only by assuming a tensile strength for the amorphous metal of an order altogether beyond any for which there is justification that the necessary rigidity of the mass can be explained, so long as the strength of the intercrystalline cement itself is assumed to be the cause.

It is, however, still possible to frame an adequate hypothesis on the basis of the theory of the amorphous intercrystalline cement. At each crystal boundary crystalline matter is separated by what is essentially an under-cooled liquid from other crystalline material, and surface-tension attractions, similar to the well-known attraction which occurs between two glass plates separated by a film of water, may be expected. It is to such forces that the strengthening effect on the mass of the metal of the crystalline boundaries is here referred. Other examples of the effects of such forces are common. Two blocks of ice with parallel faces placed loosely together will, as the excess water between the faces drains away, be drawn together by the attraction arising from surface tension with a force sufficient to weld them into one coherent whole. For the present purpose, however, the following illustration is the most suitable. The face of a cube of copper can be polished until it will, merely by adhesion to a similarly polished face, support eleven other similar cubes, each square centimetre of surface supporting nearly 100 grammes. A most interesting summary of the historical development of the theory of the connection of surface tension with solid metals is given by Dr. Desch (4). Especially is its action noteworthy in connection with the growth of crystal grains at high temperatures during annealing. The endeavour of surface forces within the mass of the metal to reduce the area of the intercrystalline regions is the undoubted cause of the disappearance of the smaller crystals and the increase of the size of the larger.

Quincke long ago put forward the view that surface-tension forces are at work between the crystal grains in a metal; the writings of Dr. Beilby are full of the idea that the surface layers of amorphous metal are controlled by the same actions; Brillouin (5) has used the hypothesis to explain the behaviour of metals under tensile stresses, and P. Curie (6) has referred to the same cause the polyhedric form of the crystals of a pure metal when fully annealed. The effects of surface actions on the microscopical structure and mechanical properties of metals have received close study from Tammann (7). A leaf of metal beaten out cold will, when raised to a certain temperature, commence to crumple and shrink. This is the result of the action of surface forces, which diminish in intensity more slowly than does the mechanical rigidity when the temperature is raised. If f is the actual strength of such a lamina at the temperature of recrystallisation, n the number of gliding planes, a_1 the surface tension in these planes, which is considered as being always less than that a in the free surfaces, then—

$$2\,n\,a_1 + 2\,a = f.$$

This equation attempts to correlate the strength of a metal with the surface tension in the regions where the metal is non-crystalline. It is exceedingly difficult, however, to obtain any kind of experimental verification. The surface-tension attractions between the moistened faces of pieces of road material have been independently utilised by Professor W. G. Fearnsides (8) to explain the strength of the structure, a theory on all fours with that here to be developed. Finally, forces of this nature have been regarded as the possible cause of the amorphous modification between the crystalline grains. Thus Rosenhain and Ewen (9) remark, "The forces . . . may possibly be of the nature of capillarity."

When two similar plates are separated by a thin film of a liquid which wets them, an attraction occurs, the force of which is—

$$\frac{2\,A\,T}{d}\text{ dynes} \quad . \quad . \quad . \quad . \quad (1)$$

where—

A is the area of the plates wetted by the liquid,
T is the surface tension of the liquid, and
d is the thickness of the liquid film.

At the crystalline boundaries in metals closely similar conditions obtain, and the same equation may be applied. In this case, however, not the atmospheric pressure, but the vectorial forces of crystallisation must be postulated as the source of the attraction. Working on this assumption, almost all of the more important mechanical properties of metals receive an adequate explanation.

It has already been mentioned that one of the chief difficulties which has hitherto faced the attempts made to explain the great strength of the intercrystalline boundaries, on the basis of the amorphous material found there, lies in the exceeding thinness of these boundaries. This very fact, however, from the present point of view, is the reason of their remarkable strength, since, according to equation (1), the attraction between the grains which opposes their separation under stress is *inversely* proportional to their distance apart. Let Fig. 1 represent part of a specimen under a stress E, equal to the elastic limit. Consider an element Δa of the surface A B on which yielding first occurs. Now the attraction of adjacent crystals across the element is—

$$\frac{2\,\Delta a\,T}{d}$$

and if α is the angle made by the element with the diameter of the piece, the resolved part in the direction of the stress is—

$$\frac{2\,\Delta a\,T\cos a}{d}$$

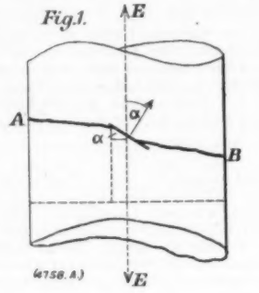
The total attraction, therefore, parallel to the direction of the applied stress is—

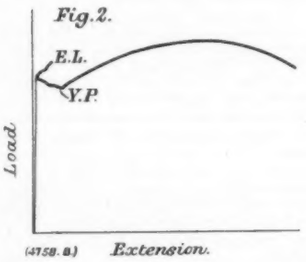
$$\Sigma\frac{2\,\Delta a\,T\cos a}{d}$$

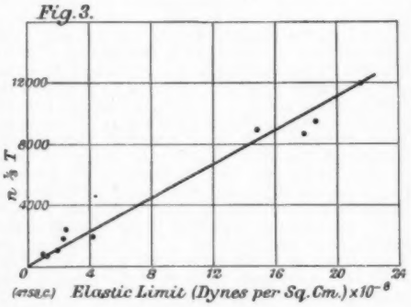
$$=\frac{2\,T}{d}\,\Sigma\,\Delta a\cos a.$$

But $\Sigma\,\Delta a\cos a$ is the area of cross-section of the specimen. Hence the resistance per square centimetre to separation along the surface A B on which the attraction is just overcome when the elastic limit is reached is—

$$E=\frac{2\,T}{d} \quad . \quad . \quad . \quad . \quad (2)$$







This result differs from that given previously (1), viz., $E = 1.5\,n\,\frac{T}{d}$, where n is the number of crystals per unit length. The dimensions of the earlier result are incorrect, and the method of derivation would lead to the result that the elastic limit is a function of the dimensions of the specimen. The equation gave results which agreed well, however, with the experimental ones, and we shall return later to an empirical relationship of a very similar type.

Static Stresses.—It is in the highest degree important to determine to what extent the requirements of such an hypothesis are in accord with the well-known effects on metals of strains both static and dynamic. Except in one small particular, the stress-strain diagram of a normal sample of iron is too well known to need discussion here. Dalby (10), however, has shown that the "yield-point" corresponds in reality to a distinctly lower resistance of the material to the stress than that at the elastic limit, the curve dipping down sharply once plastic deformation occurs (Fig. 2).

During the application of a gradually increasing tension to a specimen of a normal metal, the effects produced will, so far as the intercrystalline films are concerned, remain small, as long as the stresses applied are less than the resolved part, in the direction of the stress, of the resultant attraction of the weakest intercrystalline surface. These conditions correspond to stresses less than the elastic limit. The elongation resulting from such tensions will be the sum of the true elastic extension of the crystals, and of that due to their mutual separation. If the force be temporarily removed, the increase of length will disappear, the true elastic deformation disappearing with great rapidity, though the velocity with which the intercrystalline attractions will draw the grains back to their original positions may quite conceivably be much less. Actual flow of the viscous amorphous material, or reunion, in the space-lattices, of molecules temporarily torn away by the stresses, either of which processes may be involved, would offer an explanation of the slight viscosity effects which have been repeatedly observed below the assumed elastic limit.

When the pull on the test-piece is increased until it becomes equal to the sum of the small attractions between adjacent crystals across the weakest surface, the elastic limit is reached. A further increase of stress overcomes the adhesion of crystal to crystal; these are then drawn apart and permanent set occurs. The formation of more amorphous material by the local destruction of the space-lattice of the crystals, or actual flow of the non-crystalline modification from regions of greater pressure, prevents actual fracture occurring between the different grains.

This increase in the thickness of the films surrounding the crystals d, in equation (2), results in the reduction of the interfacial attractions which hitherto have been sufficient to withstand the stress applied, and at this point in the test a period of marked instability occurs. Every increase of the load, by increasing d, lowers the capability of the specimen of further resistance, and a more and more rapid elongation occurs. This is the yield-point. The surface-tension theory of the strength of the crystal boundaries thus affords an eminently satisfactory explanation of the loss of resistance of a metal to stress at the yield-point, and of the almost liquid-like flow which occurs there.

Once plastic flow has set in, cleavage slipping occurs within the crystals. On each plane of slip more of the vitreous modification is formed, across which the same attractions exist as between the crystals themselves. Under each load such slipping will occur as will counterbalance the new stress by the increased area across which the forces can act, and the material commences to stiffen up again, though at a rate which is not readily determinable.

The qualitative agreement between the demands of the theory and the normal stress-strain diagram is thus practically perfect. A more exact experimental check is beset by two difficulties. Hitherto no measurements of the thickness of the films have been made, whence the value of d is unknown, and further uncertainty arises from our lack of knowledge of the values of the surface tensions of the films.

It has been shown by Hook (11) that the surface tension of an under-cooled liquid is unaffected by the freezing-point, being a straight-line function of the temperature until it disappears in the neighbourhood of the critical temperature. Thus, knowing the critical temperature and the surface tension at any other known temperature, the values of T for equation (2) can be calculated, since—

$$\sigma_o = \sigma_m\frac{\theta_c - \theta_o}{\theta_c - \theta_m}$$

where—

σ_o = surface tension at room temperature,
σ_m = surface tension at melting-point θ_m deg. Cent.,
and θ_c = critical temperature.

The critical temperatures of the metals available for the present purpose are unknown, but the formula of Thorpe and Rücker (12) will yield an approximation which is sufficient for the purpose. If D_t is the density of the liquid metal at $\theta°$ absolute, D_o the density at 273° absolute, and θ_c° absolute is the critical temperature, then—

$$\frac{D_t}{2\,\theta_c - \theta} = \frac{D_o}{2\,\theta_c - 273}$$

The application of this formula will result in values for the critical temperature which can be considered as first approximations only. Since, however, the critical temperature will, in all cases, be very high compared with the melting-point—at which temperature the surface tension of the molten liquid has usually been determined experimentally—the rate of change of surface tension with temperature will be comparatively small.

* Paper read before the Iron and Steel Institute, May 5.
† These figures refer to a Bibliography at the end of the paper.

The correction to be applied to the observed value will therefore be small, and the surface tensions for the amorphous films will be known within reasonably narrow limits. For purposes of calculation of the critical temperature, D_c is taken to be the same as that of the ordinary metal—if known in the work-hardened state—since the conversion by cold work of a metal from the crystalline to the amorphous condition is accompanied by very slight changes of density.

Pure metals alone are available for the experimental consideration of the expression (2), since for these only have the surface tensions been accurately determined. With the exception of the value for cadmium, which is Quincke's, and for iron and nickel, which are not at all well known, Smith's results [13] have been adopted. The densities are those given in the tables of Landolt and Börnstein, supplemented by the excellent determinations of the densities of some liquid metals by Pascal and Journiaux [14].

A very wide range of metals was chosen, comprising antimony, copper, iron, lead, nickel, silver, tin, and zinc. The nickel alone deviated from essential purity, since it

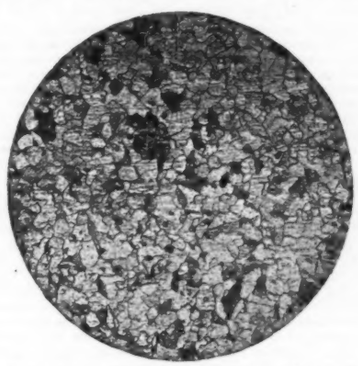


FIG. A. IRON (NORMALISED). MAGNIFIED 100 DIAMETERS AND REDUCED BY ONE-TENTH.

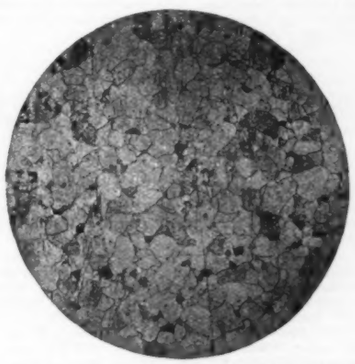


FIG. B. IRON (ANNEALED). MAGNIFIED 100 DIAMETERS AND REDUCED BY ONE-TENTH.

FIG. C. IRON (QUENCHED AND TEMPERED). MAGNIFIED 100 DIAMETERS AND REDUCED BY ONE-TENTH.

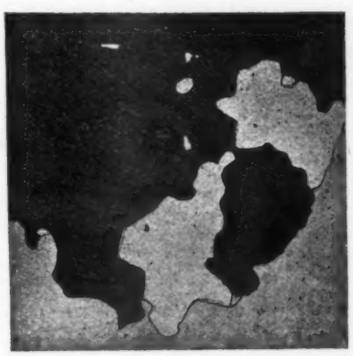


FIG. D. IRON (DRASTICALLY ANNEALED). MAGNIFIED 100 DIAMETERS AND REDUCED BY ONE-TENTH.

contained 0.79 per cent. of manganese, the remains of 1.5 per cent. of the "Thermit" element, which had been added to the molten metal to remove oxygen present in the original material, or absorbed during melting. The ingot rolled perfectly into 1-in. round bars.

The iron was melted by the coke crucible process from a specially pure Swedish bar iron containing :—

	Per Cent.
Carbon	0.03
Silicon	0.02
Manganese	0.10
Sulphur	0.01
Phosphorus	0.015

The analysis of the ingot being :—

	Per Cent.
Carbon	0.049
Silicon	0.04
Manganese	0.03
Sulphur	0.02
Phosphorus	0.016
Aluminium	trace
Iron (by difference)	99.84

It will be seen that the ingot is one of the purest ever cast by this process. About seven minutes before pouring 0.04 per cent. of aluminium was added to "kill" the metal, a clean, sound ingot, 2 in. square and weighing 28 lb., being produced. This was rolled down into 1-in. round bars without any difficulty. This metal was examined in three different conditions :—

1. Normalised—*i.e.*, reheated to 900 deg. Cent., drawn and cooled in air.

2. Annealed at 900 deg. Cent., and cooled over 12 hours.

3. Reheated to 900 deg. Cent., quenched in cold water, and subsequently tempered at 650 deg. Cent. This temperature was chosen for the tempering, since it was well above that (520 deg. Cent.) at which iron deformed by cold work reverts to the soft state [15]. The small amount of carbon present would tend also to revert more or less to that condition in which it occurs in the other samples.

The microstructures at a magnification of 100 diameters of the iron in its three conditions are shown in micrographs Figs. A, B, and C. Micrograph Fig. D is a reproduction of the same iron which had received an exceedingly drastic annealing. This bar was reheated to 900 deg. Cent., kept at that temperature for 15 hours, and then cooled over another 40 hours. As will be seen from the figures, the resulting microstructure was remarkably irregular. When etched, most of the crystals could be seen with the naked eye, so coarse was the structure, but interspersed throughout the mass sometimes in patches of considerable size, sometimes in isolated grains, were other crystals as small as those constituting the samples as received from the rolls or normalised. The explanation of this fact is unknown to the author, though it would seem undoubtedly to be connected with the remarkable recrystallisation which occurs at the point A3. Micrograph Fig. D is of interest in another connection. Round several of the crystals the boundaries are double, the result of the small percentage of carbide present being extruded to these regions. The amount of carbide thus present is not inconsiderable, whence it would appear that the solubility of Fe_3C in an iron at room temperature is considerably less than 0.049 per cent. This figure is the concordant mean of three determinations made by the wet combustion process.

With the exception of the samples of iron and nickel, the test-pieces were all prepared from bars 1 in. in diameter and 12 in. long, cast in dry sand moulds, and examined in that condition. Twinning within the crystals was thus eliminated, and the more or less hypothetical changes in the mechanical properties which might arise therefrom are avoided.

The test-pieces for the tensile tests were 8 in. long, with 2 in. in the centre turned accurately to a diameter of 0.564 in. Each change of diameter was gradual, sharp angles being carefully excluded. The tests were carried out on the 10-ton centre of a Buckton testing-machine. The elastic limit, or more properly the limit of proportionality of stress and strain, was determined in the cases of the copper, silver, nickel, and the irons, with the aid of the Metzger extensometer, reading to 0.0001 in. In the remaining tests it was somewhat less exactly determined as that stress at which permanent elongation could be first observed with dividers—*i.e.*, an elongation of 0.01 in. on a gauge length of 2 in., or 0.005 per cent.

The results are collated in Table I.

For purposes of comparison with equation (2) the elastic limit must be converted to absolute measure—*i.e.*, dynes per sq. cm. In Table II. the re-calculated values of the elastic limit, the surface tensions of the films obtained, as already indicated, and their thickness calculated by means of the equation, are collected.

TABLE I.

Material.	Elastic Limit. Tons per Sq. In.	Maximum Stress. Tons per Sq. In.	Elongation per Cent. on 2 In.
Copper	1.52	9.0	22.0
Zinc	2.64	2.64	0.0
Antimony	0.69	0.69	0.0
Nickel	11.5	36.7	66.4
Lead	0.60	0.98	54.5
Tin	1.20	2.40	36.5
Silver	1.40	8.0	60.0
Iron (annealed)	9.61	21.1	47.0
" (normalised)	12.0	21.8	47.5
" (quenched and tempered)	14.0	23.2	48.0

TABLE II.

Material.	Elastic Limit. $\times 10^{-8}$ Dynes per Sq. Centimetre.	Surface Tension of Films. Dynes per Sq. Centimetre.	Thickness of Films. Centimetre.
Lead	0.93	443	9.5×10^{-6}
Antimony	1.04	285	5.5×10^{-6}
Tin	1.86	501	5.4×10^{-6}
Silver	2.17	1040	9.5×10^{-6}
Copper	2.35	1246	11.0×10^{-6}
Zinc	4.08	726	3.55×10^{-6}
Nickel	17.8	1350	1.52×10^{-6}
Iron (annealed)	14.8	1350	1.82×10^{-6}
" (normalised)	18.6	1350	1.45×10^{-6}
" (quenched and tempered)...	21.6	1350	1.25×10^{-6}

With the exception of the values for antimony and zinc, an increase in the surface tension results in all cases in a corresponding rise of the elastic limit. Both of these metals broke absolutely without measurable elongation or reduction of area. The elastic limit and maximum stress thus coincided, and it is exceedingly probable that fracture occurred under a deformation which was considerably less than that first recognisable in the other tests. An examination of the fracture in the two cases indicated also that cleavage, rather than intercrystalline fracture, had occurred. It is also possible that the turning in the lathe from the original bar has caused a deterioration of such exceedingly brittle metals. The results thus afford strong evidence of the truth of equation (2), and of the assumption of surface-tension attractions in the amorphous intercrystalline cement upon which it was derived. Incidentally, also, they appear to the author to supply further evidence for the belief in the existence of the amorphous intercrystalline cement itself.

The number of metals, the thickness of the intercrystalline films of which have been measured, is too small to draw any sweeping generalisation. It is very interesting, however, to note that, without exception, the films decrease in thickness in passing from left to right of the Periodic Table. Thus copper, zinc, iron, and nickel all occur in the first long period in groups 1, 2, and 8. The thickness of the copper films is 11.0×10^{-6} centimetres, that of the zinc 3.5×10^{-6}, and of the iron and nickel 1.5×10^{-6} centimetres.

The decrease of the thickness of the films in the samples of iron as the rapidity of cooling of the samples of iron increases is noteworthy, and will be considered again later. With the exception of one or two-hundredths per cent. of the carbon, and the same amount of sulphide of manganese, the whole of the impurities are in solid solution, and in all probability in the same condition in all the specimens. The only essential difference between the three samples lies in the crystalline size.

The relationship given previously,[1] namely :—

$$E = 1.5\, n \frac{T}{d}$$

contains a factor which depends on the size of the crystal grains. This result is, of course, in agreement with the practical observation that a fine-grained metal has a higher limit of elasticity than one coarsely crystalline, other things being equal. The product nT was shown to increase with the elastic limit, but a better empirical relationship is obtained by putting—

$$E \propto n^{\frac{1}{2}} T \quad . \quad . \quad . \quad . \quad (3)$$

Such an expression is purely empirical, but, as will be seen from the results recorded in Table III., and plotted in Fig. 3, it is in most satisfactory accord with the experimental results.

The more or less regular increase of fineness of the crystallisation of the metals, *i.e.*, of *n*, with the increase of the surface tension is an interesting point. Since the tendency of surface forces is to decrease the area over which they act, a decrease of the number of crystals per unit volume with an increase of T would rather have been expected.

The reason for the introduction of a term dependent on the size of the crystals is not far to seek. The inter-

crystalline regions, as a result of the attractive forces exerted within them, react on the whole mass as a strengthening framework. The greater the amount of this scaffolding the more resistant to deformation will the whole structure be. In addition, in an interlocking structure, such as an aggregate of crystals of iron, no direct separation of crystals can occur without producing in some part of the mass an intercrystalline shear. Now the greater the number of the crystals present along such a plane the greater will be the interpenetration of the adjacent grains, and hence the rigidity of the specimen. This is the explanation put forward by Professor J. O. Arnold to explain the strength of the crystal boundaries in 1906 (16).

TABLE III.

Material.	No. of Crystals per Cm. (n).	Surface Tension T.	$n^{\frac{1}{3}} \times T$.	Elastic Limit. Tons per Sq. In.
Lead	4.0	443	703	0.60
Antimony	7.5	285	556	0.69
Tin	5.9	501	905	1.20
Silver	5.5	1040	1835	1.40
Copper...	8.7	1246	2563	1.52
Zinc	15.7	726	1818	2.64
Nickel	256.0	1350	8570	11.5
Iron (annealed) ...	276.0	1350	8788	9.61
,, (normalised) ...	343.0	1350	9450	12.0
,, (quenched and tempered)	690.0	1350	11930	14.0

The mutual attraction between the molecules of a liquid, which is the ultimate source of the phenomenon of surface tension, must result also in what is effectively a state of internal pressure. This "intrinsic pressure" will oppose any change of volume, and the liquid must therefore possess a tensile strength. For water the intrinsic pressure or tensile strength is about 70 tons per square inch. The same term is found in Van der Waals' well-known equation as the quantity $\frac{a}{v^2}$, which must be added to the observed pressure, a being a constant for each material, and v the specific volume. In considering the possibility of extending this equation of Van der Waals to the solid state, Traube (17) concluded that the hardness of a metal is determined by its intrinsic pressure. Now, although no exact expression has so far been found for the connection between intrinsic pressure and surface tension, it is obvious that high intrinsic pressures must be accompanied by high surface tensions, since the surface tension is a manifestation of the same cohesive force as that which causes intrinsic pressure. This relationship of Traube's is therefore of considerable interest from the point of view of the present theory.

In Table IV. the elastic limits, maximum stresses, and Brinell hardness numbers (measured under a pressure of 500 kilogs.) are collected, along with the values (Traube's) of the intrinsic pressures. In considering the results, the manganese present in solid solution in the nickel must not be lost sight of. Except in regard to the maximum stress of antimony, Traube's theory is strikingly confirmed, the tensile strength and Brinell hardness number in every case increasing with an increase of the intrinsic pressure. If the zinc and antimony results are excluded (these were the metals also which occupied anomalous positions in Table II.), the elastic limit also increases with the intrinsic pressure. The three tests made on the pure iron give rise to a point of considerable interest. In a ductile metal such as this, it has been conclusively proved that fracture in tension occurs within the crystals themselves, and not in the intercrystalline boundaries. Now there is no reason to suppose that

TABLE IV.

Material.	Intrinsic Pressure Megabars.	Elastic Limit. Tons per Sq. In.	Maximum Stress. Tons per Sq. In.	Brinell Hardness. Pressure, 500 Kilogrammes.
Lead	51,500	0.60	0.98	Too soft to measure
Tin	73,100	1.20	2.40	Ditto, but harder than lead
Zinc	108,900	2.64	2.64	29.7
Antimony	120,000	0.69	0.69	Crushed
Silver...	161,900	1.40	8.00	—
Copper	236,100	1.52	9.00	45
Iron (annealed) ...	323,900	9.61	21.1	70
Iron (normalised)...	324,900	12.0	21.8	83
Iron (quenched and tempered	323,900	14.0	23.2	105
Nickel	324,600	11.5	36.7	109

the heat treatments applied would appreciably alter the state of the crystalline matter, the space-lattices remaining the same. Hence, beyond a certain comparatively small stiffening up, due to the greater amount of the amorphous cement present, one would not expect the maximum stresses in the three cases to differ appreciably. This is shown to be the case, the increase in the maximum stress from least to greatest being only 10 per cent. On the other hand, according to the theory here advanced, the magnitude of the elastic limit is intimately connected with the boundaries between the crystals, and the change in this quantity in the cases under consideration is no less than 46 per cent. To the author this seems striking evidence that the conditions governing the elastic limit are, as his theory demands, essentially different from those governing the maximum stress. Probably the most striking proof of the truth of this fact is supplied by figures published by Professor Arnold in a remarkable paper on "Factors of Safety in Marine Engineering" (18). The material examined was a casting containing 0.4 per cent. carbon, 0.26 per cent. silicon, and 0.10 per cent. manganese, together with low sulphur and phosphorus. The tensile tests of the material "as cast," and after a drastic annealing, were as follow :—

Condition of Steel.	Elastic Limit. Tons per Sq. In.	Yield Point. Tons per Sq. In.	Maximum Stress. Tons per Sq. In.	Elongation per Cent. on 2 In.	Reduction of Area per Cent.	Bending Angle.
As cast ...	16	17.6	25.8	5.0	5.6	21 deg.
Annealed	4	7.4	24.3	32.5	37.7	180 deg. (unbroken)

Although the over-annealing has caused a loss of tensile strength of only 5 per cent., the true elastic limit has fallen 75 per cent. Further figures of a similar nature are included later.

(To be continued.)

CONTRACTS.—The Ripon Corporation and the Ripon and Wath Rural District Councils have placed an order with Messrs. Merryweather and Sons for a "Hatfield" petrol-motor fire-engine of the new "Light Brigade" design, capable of delivering 250 gallons per minute, and fitted with a first-aid tank, from which the pump can take a supply of water for delivering a small jet immediately the scene of action is reached. A 35-ft. extension ladder and 3600 ft. of canvas delivery hose will be included in the equipment.

THE WORLD'S STEEL.—The production of steel in the principal countries of the world in 1913 (the last year of fairly general peace) was as follows :—United States, 31,301,000 tons; Germany, 18,959,000 tons; Great Britain 7,664 000 tons; Russia, 5,111,000 tons; France, 4,635,000 tons; Austria and Hungary, 2,683,000 tons; Belgium, 2,467,000 tons; Italy, 846,000 tons; Sweden, 583,000 tons; and Spain, 320,000 tons. The United States accordingly now make about three-fourths as much steel as all other countries put together.

THE LATE MR. JOHN FREDERICK WOLFF.—We regret to have to announce the death, which occurred on Monday last, the 15th inst., at his residence, "Rosapenna," Lyford Road, Wandsworth Common, of Mr. John Frederick Wolff. Mr. Wolff was 64 years of age. He was chairman and managing director of the Railway Signal Company, Limited; director of the Horsehay Company, Limited; of the Globe Pneumatic Engineering Company, Limited; and of Messrs. Ransomes and Rapier, Limited; and managing director of Messrs. J. F. Wolff and Co., Limited, engineers, Sanctuary House, Westminster, London, S.W.

TRADE WITH JAPAN.—The Swedish Minister in Tokio, Mr. Gustaf Wallenberg, is at present on a visit to Sweden and has given some interesting information about Japanese affairs. For 1915 the imports showed a reduction of 130,000,000 yen, whilst the exports increased 170,000,000 yen. The statistics do not comprise war material, of which the exports to Russia during 1915 are stated to amount to 80,000,000 yen. Prices for food have not risen in Japan on account of the war, rice, in fact, has fallen in price on account of recent good harvests; on the other hand, wages have increased, for unskilled labour from 25 sen to 80 sen per day (100 sen equal to 1 yen, about 2s.). Japan is steadily increasing her hold upon the Chinese market, and European goods may find their way into China through the medium of Japan. Sweden, aided by the excellent direct Swedish-Danish East Asiatic lines, has greatly increased her trade with Japan and has advanced from being the fourth to coming second in this connection, being next to England.

THE RHENISH-WESTPHALIAN COAL SYNDICATE.—At the last meeting of the mine-owners of the Rhenish-Westphalian Coal Syndicate, some opposition was offered against the new classification of coke, and the matter was therefore referred to a committee for further investigation. The coal production measures, on the other hand, were passed. An increase of the production of coke has been aimed at almost ever since the war broke out, more especially so to increase the available quantities of by-products, sulphate of ammonia, benzole and tar, which are urgently wanted. In order to increase the demand for coke at the commencement of the war, the syndicate raised the prices for coal and lowered the coke prices. Later, the syndicate several times found it expedient to raise the price for coke, first 2 marks from September 1, 1915, and then in January, 1916, 1.50 marks. The present necessity for increasing the production of coke is a result of the increased requirements for coke by-products, which lately have manifested themselves in the eastern provinces. The supply of these districts formerly principally came from Upper Silesia and Austria, but now the Rhenish-Westphalian concerns more than hitherto have been called upon to supply the eastern portions of the country. The quantity of coal and coke despatched during February, says the report, shows some falling-off as compared with the previous month. The aggregate sale of coal, including the coal required for coke and briquette manufacture and for the working of the mines, amounted to 7,657,412 tons, and the production to 7,712,555 tons.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Glasgow Pig-Iron Market.—From Wednesday onwards last week the pig-iron warrant market remained in the featureless state which had marked the earlier days. On Wednesday and Thursday buyers quoted 90s. per ton, although there were no sellers, but on Friday even buyers' quotations were conspicuous by their absence. Buyers were again in evidence on Monday, quoting 90s., but still without avail. Settlement price remains at 90s., and stocks are diminishing rapidly. No change took place on Tuesday, when buyers still offered 90s. per ton, nor yet to-day (Wednesday).

Scotch Steel Trade.—Just as was expected, the recent Order in Council in curtailing the export of steel has already had beneficial results, as the enforced restrictions have liberated a considerably increased tonnage for home consumption. In addition, owing to the difficulty and frequent delay in procuring the necessary licence for shipment, the export demand has fallen off to a certain extent. Notwithstanding this, however, and the enlarged output capacity of the many steel-producing works running at full pressure, it would almost seem as if our own Government would absorb every available ton of material, leaving the surplus very much a minor quantity. To meet the demand involves extreme overtaxing all along the line, and arrears are accumulating even at that. Of course, some allowance must be made for the requirements of our Allies, whose demands are equally pressing with our own. Shell bars are a heavy business. The home market for ordinary mercantile orders stands much on the same level as last week, no new developments falling to be noted. Meantime values keep strong, nor is it in the least probable, looking to the high cost of raw material and the ever-increasing price of labour, that any considerable change may be expected for some time. Angles are now generally quoted in the region of £14 per ton; ship-plates may be 13*l.* 10s., or 13*l.* 15s., with boiler plates about 1*l.* per ton over this figure—all less 2½ per cent.

Malleable Iron Trade.—Malleable-iron makers report a continued and well-sustained demand for the whole of their enormous output, at the same time regretting their utter inability either to supply all the demands or to deliver these in anything like the specified time. Naturally one cause of this extra pressure is to be found in the embargo placed by Government upon steel, customers frequently specifying now for bar-iron in place of steel when it is possible to use either. Although "Crown" bars are quoted 14*l.* per ton, even higher rates are being asked for some of the better qualities, with full extras in every case.

Scotch Pig-Iron Trade.—Now the Government has taken the entire control of the export of pig-iron, the quantity available for shipment has been considerably lessened, and there is, in consequence, a better chance of the home requirements being adequately met. Taken generally, pig-iron, expecially hematite grades, is none too plentiful, and it is with difficulty that the supply can keep pace with the demand—indeed, there is just a possibility of a decided scarcity of iron ere long, as the producing furnaces are quite unable to meet the exceptional demands made upon them. The demand for hematite keeps very strong, and the fact that the services of many men have been transferred to the hematite furnaces from other departments is like to make a felt scarcity of the ordinary foundry grades. Prices keep firm, and are practically unchanged during the week, having apparently settled down on the basis of maximum rates. Makers' (No. 1) iron therefore remains steady at :—Clyde, Calder, Summerlee and Langloan, 130s. per ton; Gartsherrie, 131s. 6d. (all shipped at Glasgow); Eglinton, 126s. 6d.; Glengarnock, 130s. (both at Ardrossan); Dalmellington, 126s. 6d. (at Ayr); Shotts and Carron, 130s. (both at Leith).

Engineering After the War.—Under the auspices of the Institution of Engineers and Shipbuilders in Scotland, a meeting was held in the Royal Technical College on Tuesday of this week for the purpose of considering the position and development of the iron, steel and engineering trades after the war. Similar meetings are being held in the chief industrial centres of the country with the object of impressing upon the public the national value of these trades, not only from a financial point of view, but as an important asset in our relationships with our present Allies. It is firmly realised that everything possible must be done to strengthen our position as a manufacturing nation; therefore the discussion of all questions relating to such industrial development as will improve our attitude towards foreign competitors is of paramount significance. An able address was delivered by Mr. T. C. Elder, of the British Electrical and Allied Manufacturers' Association, who chose as his subject "Engineering Industry in the Economic War," the subsequent discussion being engaged in by several prominent Scottish engineers.

MANUFACTURE OF DYNAMITE.—Samples of Australian diatomite can be obtained by manufacturers interested on written application to the Imperial Institute, South Kensington, London, S.W.

OUR LOCOMOTIVE EXPORTS.—Our locomotive exports continue to decline, although they still exhibit a little importance. In April we exported engines and parts of engines to the value of 89,914*l.*, while in April, 1915, the corresponding exports represented a value of 46,830*l.*, and in April, 1914, a value of 221,154*l.* The value of the aggregate shipments for the first four months of this year was 420,401*l.*, against 905,843*l.* and 1,445,826*l.*

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—The scarcity of pig-iron is acutely felt, and the local committee appointed to regulate supplies continues to experience difficulty in discharging its duty, but the distribution is giving more satisfaction, and traders are not without hope that the situation will improve. There is an outcry for increased production, but with the present shortage of labour this is quite impossible. Already many establishments are kept going with fewer men than in normal times. The only means of enlarging the output appears to be by releasing men from the army to work the furnaces, mines, and other necessary branches. Export trade is at a standstill. The nominal export quotation for No. 3 Cleveland pig is 35s., but doubtless a higher price would readily be paid if iron was forthcoming and licences for shipments were obtainable. For home consumption No. 3 remained at 82s. 6d., and that price was also named for the lower qualities. Quotations for No. 1 Cleveland were put at 4s. to 5s. above the prices named for No. 3.

Hematite Iron.—The position in the East Coast hematite pig-iron trade is very similar to that prevailing in the Cleveland pig branch. Iron is practically unobtainable for early delivery, and most makers have committed themselves ahead as far as they care to go. Customers at home and our Allies are pressing for deliveries against contracts. The export quotation of Nos. 1, 2, and 3 is 140s. and upward, and for home use the price remains at 122s. 6d.

Stocks and Shipments of Pig-Iron.—Stocks of pig-iron are now very low, and are still being reduced. Producers have none. The quantity of Cleveland pig held in the public warrant stores here stands at 35,009 tons, of which 33,418 tons are No. 3, and 1591 tons other qualities of iron deliverable as standard. So far this month 4527 tons of No. 3 and 869 tons of standard iron, a total of 5396 tons, have been withdrawn from the stores. Shipments of pig-iron from the Tees are, under all the circumstances, on a satisfactory scale. To date this month they average 1963 tons per working day, the total despatches reaching 29,444 tons. To the same date last month the loadings totalled 29,241 tons, or a daily average of 1950 tons, and for the corresponding part of May last year the clearances were officially returned at 6333 tons, or an average of 422 tons per working day.

Coke.—Demand for coke is large, and is by no means easily met. Local requirements are heavy and medium blast-furnace kinds are very firm at 28s. at the ovens. Good foundry sorts are 47s. to 47s. 6d. Gas-house coke is in the neighbourhood of 27s.

Foreign Ore.—At port of despatch the f.o.b. price of Rubio of 50 per cent. quality is fully 18s. In the open market the freight Bilbao-Middlesbrough is 18s. 6d., making the ex-ship Tees price of Rubio 36s. 6d.; but controlled consumers are privileged, through the Government, to arrange steamers from Bilbao at 17s., so that to them the ex-ship Tees price of best Rubio is only 35s. Imports of foreign ore to the Tees so far this month amount to 104,798 tons.

Manufactured Iron and Steel.—The attention of manufacturers of finished iron and steel continues to be absorbed on Government work, for which there is still great pressure for delivery, and little notice is taken of the numerous ordinary commercial inquiries. Prices all round are very strong, and there is some talk of advancing certain descriptions. The following are among the principal market quotations: Common iron bars, 13*l.* 15s.; best bars, 14*l.* 2s. 6d.; double best bars, 14*l.* 10s.; treble best bars, 14*l.* 17s. 6d.; packing iron (parallel), 10*l.*; packing iron (tapered), 11*l.* 15s.; iron ship-plates, 11*l.* 10s.; iron ship-angles, 13*l.* 15s.; iron ship-rivets (¾-in. diameter), 16*l.* 10s.; iron ship-rivets (⅞-in. diameter), 17*l.* 10s.; steel bars (no test), 14*l.* 10s.; steel ship-plates, 11*l.* 10s.; steel ship-angles, 11*l.* 2s. 6d.; steel sheets (singles), 18*l.* 10s.; steel sheets (doubles), 18*l.* 15s.; steel joists, 11*l.* 2s. 6d.; and heavy steel rails, 10*l.* 17s. 6d.

Trade Statistics.—The returns of the Middlesbrough Chamber of Commerce for the first quarter of the year, just issued, show that of the 77 blast-furnaces within the port of Middlesbrough, 44 were in operation at the end of March last, or two below the number blowing at the same date last year. The make of pig-iron for the first three months of the year is given at 551,000 tons, of which 236,000 tons were Cleveland pig, and 315,000 tons hematite, spiegel, basic and other special irons. For the previous quarter the output was 533,000 tons, of which 247,000 tons were Cleveland, and 286,000 tons hematite, &c., and for the first three months of 1915 the production amounted to 552,000 tons, 322,000 tons being Cleveland iron and 230,000 tons hematite, &c. Imports of foreign iron ore into Middlesbrough last quarter reached 441,021 tons, as compared with 489,437 tons for the previous three months, and 388,330 tons for the first quarter of last year. The total value of goods, other than coal and coke, exported to foreign and colonial destinations from Middlesbrough during the first quarter of the year reached 3,448,978*l.*, as compared with 1,488,627*l.* for the corresponding period a year ago—an increase of 1,960,351*l.*

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

South Yorkshire Coal Trade.—As this is the season for the opening of the shipping business, chief interest is directed to the export trade. All the Baltic ports, which would now be open in normal times, are inaccessible to coal traffic for reasons which need not be stated here, but Russia is still receiving large supplies of coal via the Archangel route. The other Allied countries, France and Italy, are also taking more than the average quantities, for this is regarded in the colliery circles to be the most favourable period for the replenishing of stocks. The intervention of the coal exportation restrictions prevent the shipments denuding the home market, but as the Coal Prices (Limitation) Act does not apply to this section of the trade, very high prices are being realised. Bunkers are fully 25s. per ton, whilst cobbles, nuts, and slacks are 19s. per ton. It is stated that for certain shipments almost any price will be paid. The problem, however, is not one of prices, but of supplies and delivery. The home market has a very strong tone. House coal meets a decreasing demand, but any surplus is readily converted to bunkering purposes, or absorbed in the gas companies' contracts. Manufacturing fuels are a difficult market, and the supply is short, thus creating considerable trouble in the providing of adequate quantities to keep works running. The sifting of "dispensable" men from the collieries is in progress at nearly all the South Yorkshire collieries to-day, and the process is not likely to have any beneficial effect upon the output. With regard to the gas companies' annual contracts, which are now open, it is stated these are on an unusually heavy scale, due to the increased use of gas both in the works and the homes. Collieries, however, seem to be indifferent as to whether they secure the contracts or not, for they are not faced with any possibility of having their stocks left on their hands. Indeed, the gas companies' representatives display some anxiety as to whether the contracts will be fixed up by the specified date in June. Quotations:—Best branch hand-picked, 20s. 6d. to 21s. 6d.; Barnsley best silkstone, 18s. 6d. to 19s. 6d.; Derbyshire best brights, 17s. 6d. to 18s. 6d.; Derbyshire house, 16s. to 17s.; best large nuts, 15s. 6d. to 16s. 6d.; small nuts, 15s. to 16s.; Yorkshire hards, 16s. 6d. to 17s. 6d.; Derbyshire hards, 16s. to 17s.; best slack, 12s. to 13s.; seconds, 11s. to 12s.; smalls, 8s. to 9s.

Iron and Steel.—New and increasing demands upon Sheffield industries have only served to exemplify the scarcity of raw materials. Several of the new national munition factories have now got into full working order, and the additional call for steel is a hard problem to solve. The fact that new furnaces are being built locally and in other parts of the country has given rise to great satisfaction; but in view of the mammoth aggregate steel consumption in Sheffield alone the new developments are hardly on so great a scale as to materially affect the general situation. War purposes are reported to absorb 80 per cent. to 90 per cent. of the supply, so that little is available for other purposes. Basic steel is fast becoming one of the hardest commodities to obtain, for now the American shipments are so small as hardly to be accounted worthy of note. Last year the transatlantic supplies were round about 30,000 tons monthly, but in April of this year the total was no more than 6,000 tons, and is expected to be even less during the current month. The market has but little to sell, and that, too, only at a great advance in price. The local steel trade is working under very heavy pressure. The file business is especially brisk. In the iron and steel market pig-iron is scarce, and a slight advance on last week's markings. Hematites are wanted in larger quantities, and there has been some heavy buying recently in West Coast brands. Forge and foundry irons, particularly the Lincolnshire qualities, are just now in great demand. Swedish billets are an advance of 3*l.* on the month, being quoted at 35*l.* as against 32*l.* in April and 12*l.* before the war. Even at this phenomenally increased price buyers are not able to get sufficient quantities to meet their requirements, for Swedish makers contend that the restriction in the shipments of South Yorkshire coal adversely reacts upon their output. Some confirmation of the need for this class of fuel is to be found in the fact that South Yorkshire hards are now marked at 4*l.* per ton at Stockholm. Steel scrap and wrought iron are eagerly inquired for, and current high prices paid. A good deal has recently been done on the suggestion of the responsible Government Departments in the way of abolishing working during meal hours in the large munition establishments, and also in the abolition of the continuous week-end stretch. It has been found that the result of these war-time innovations has not been an acceleration of output. A labour problem which affects the cutlery trade is the prospective loss of further workmen by the new recruiting measures, and also a sifting of the "indispensables." The manufacturers have replied to the authorities that they are already working on the smallest staff possible if army contracts are to be completed. Sheffield protests have resulted in the withdrawal of the embargo placed by the Order in Council upon the importation of stag horn, buffalo horn, and ivory, which are necessary for the execution of War Office work. It has been ascertained that the supply of garden tools by the Sheffield Agricultural and Implement Machinery manufacturers is equal to the demand, and that there is every likelihood of the same satisfactory report being made with regard to farm implements, although manufacturers have had a harassing time to supply the necessary quantities of hay-forks and rakes. Indents for tool-steel (for France), choppers, files, saws, machets, sheep-shears, constitute the principal overseas business.

NOTES FROM THE SOUTH-WEST.

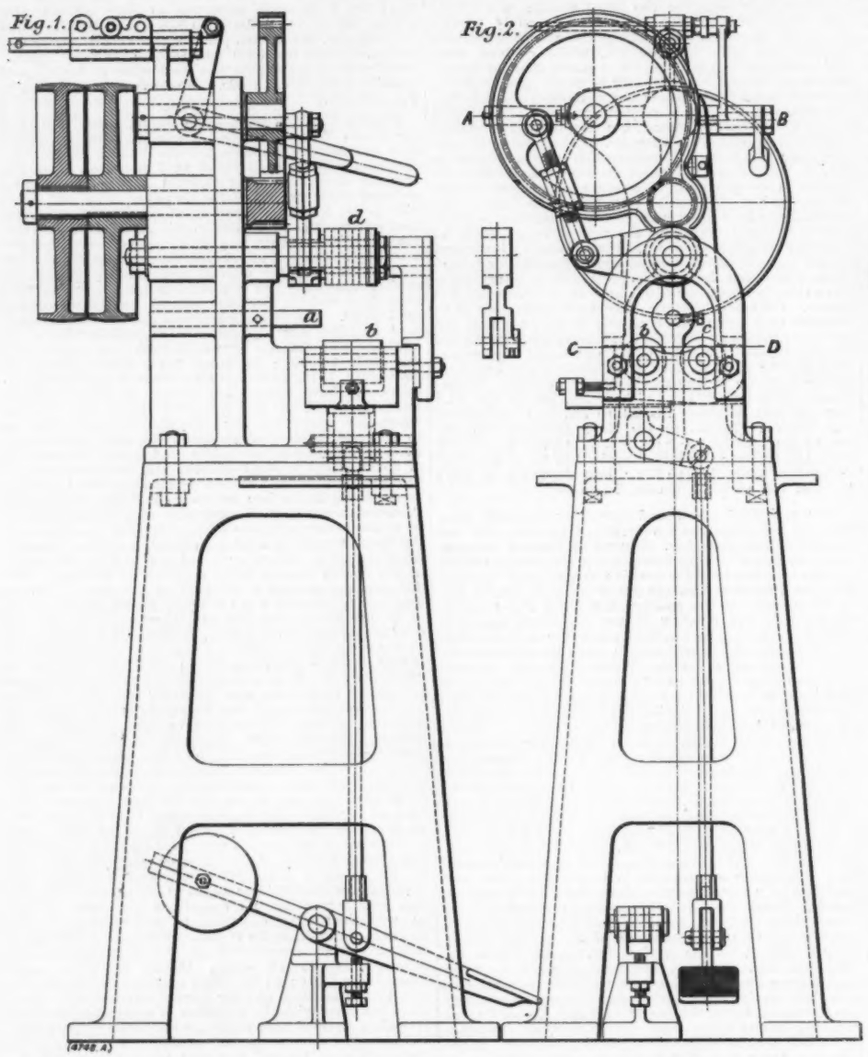
Cardiff.—Tonnage has arrived freely and loading pressure has been fully maintained; outputs have been rather heavier and more coal has been available after Government requirements have been provided for, but some time will clearly elapse before coalowners will be able to fully meet their contract engagements. The best Admiralty large steam coal has been, to some extent, nominal; secondary qualities have made 54s. to 56s.; Monmouthshire Black Veins, 54s. to 55s.; ordinary Western Valleys, 53s. to 54s.; Eastern Valleys, 49s. to 51s.; best bunker smalls, 32s. to 33s.; and cargo smalls, 24s. to 28s. per ton. In bituminous coal best households have brought 23s. to 24s. per ton at the pits; No. 3 Rhondda large, 56s. to 58s.; No. 3 smalls, 35s. to 38s.; No. 2 Rhondda large, 47s. to 48s.; and No. 2 smalls, 26s. to 28s. per ton. The latest quotations for patent fuel has been 50s. to 55s. per ton. Special foundry coke for export has made 60s. to 65s.; good foundry coke, 55s. to 60s.; and furnace coke, 45s. to 50s. per ton.

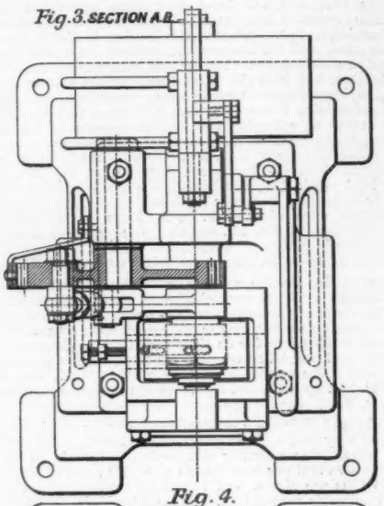
Western Trade Matters.—The second annual report of the South Wales Transport Company, Limited, states that the balance available for dividend is 3662*l.* The directors propose a dividend of 7 per cent. upon the ordinary shares, carrying forward 1320*l.* The paid-up ordinary share capital of the company is 30,000*l.* The high prices current for coal is, of course, affecting gas companies.—The promoters of the Aberdare and Aberamen Gas Bill, now pending in Parliament, state that the company's charges as at present authorised are not sufficient to pay for manufacture and to provide for capital charges.—The Winnfield steamer, carrying 5800 tons dead weight, has been bought for Cardiff owners for 77,000*l.* The vessel, which was built at West Hartlepool in 1901, has changed owners several times. In 1907 she was disposed of for 22,000*l.*; in April, 1915, she made 38,000*l.*; in June, 1915, 41,000*l.*; and in November, 1915, 56,500*l.*—The Newport Harbour Commissioners have approved a scheme of river improvements by which the Usk is to be deepened from a point where the Alexandra Dock Company's works end up to Newport Bridge, at an estimated cost of 12,000*l.*; there will also be an annual estimated cost for dredging of 2500*l.* The works suggested are, however, only to be carried out at the "earliest practicable date." Differences which had arisen between the Newport Harbour Commissioners and the local dock company with reference to a deep-water entrance channel have been settled by the appointment of a joint committee.—John Lysaght, Limited, had an altogether record year in 1915, the profits of the twelve months being returned at 414,764*l.* The directors recommend a dividend at the rate of 10 per cent. per annum upon the ordinary shares, with a bonus of 3s. per share, both free of income tax; the reserve fund is increased to 750,000*l.*, 40,000*l.* being also carried to the steel works redemption account and 10,000*l.* to the workmen's provident fund; the large balance of 633,005*l.* is also to be carried forward subject to income tax excess profits tax and directors' fees.—The Public Trustee has announced that he considers that it will be necessary at some future time to open a Cardiff or a Swansea branch.—The Newport Harbour Board's dredging plant has been hired by the Alexandra Docks Company.—The directors of the Cardigan Steamship Company, Limited, recommend a dividend at the rate of 20 per cent. per annum for the past year, carrying forward 29,048*l.*—The Anglo-Spanish Coaling Company, Limited, has declared a dividend of 20 per cent. upon its ordinary shares for the past year free of income tax. The annual meeting of the company was held at Cardiff on Friday, and Lord Rhondda, who presided, said although the shareholders ought to be satisfied with the past year's working, its operations had been carried on with increasing difficulty in consequence of the shortage of coal in South Wales for shipment; difficulties had also been experienced in obtaining licences to export. Depôts at Oran, Cadiz, Barcelona and Valencia had been in operation continuously during the past twelve months, and the directors proposed to open other branches with the intention of completing a chain of coaling stations from Bilbao to Barcelona; operations had already been commenced at Bilbao and Vigo.—The first sailing of Cunard steamers from Avonmouth to Canada has been fixed for Tuesday, May 23. The first steamer to arrive at Avonmouth from Montreal will leave that port on Thursday, May 25.—Lord Rhondda has retired from the board of the Ebbw Vale Steel, Iron and Coal Company, Limited. His lordship had not only been a director he was also vice-chairman.—It is understood that maximum freights for coal from this country to France have now been fixed by agreement between the British and French Governments and a number of shipowners. The maximum freights, which are to come into operation June 1, will show a considerable reduction; to Havre or Dunkirk the maximum from South Wales will be 25s. 6d. per ton, as compared with 33s. per ton as at present.

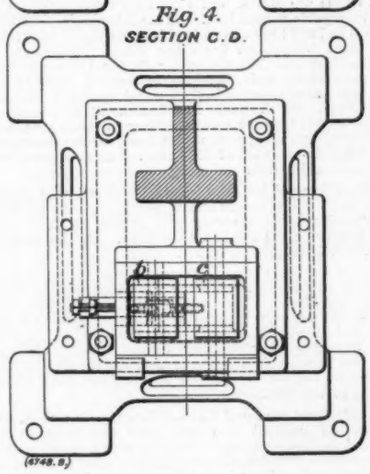
OUR COAL ABROAD.—The export of coal from the United Kingdom in the first four months of this year were 12,251,558 tons, as compared with 14,989,490 tons in the corresponding period of 1915, and 22,644,387 tons in the corresponding period of 1913. These totals were increased by the addition of coke and patent fuel to 13,175,345 tons, 15,684,094 tons, and 23,680,027 tons respectively. Bunker coal was also shipped for the use of steamers engaged in foreign trade to the extent of 4,236,038 tons, 5,154,395 tons, and 6,659,730 tons respectively. France imported 5,308,702 tons of British coal to April 30, this year, as compared with 5,398,042 tons and 4,769,297 tons; and Italy 1,751,224 tons, as compared with 2,222,493 tons and 3,051,707 tons. The shipments to the following countries exceeded 500,000 tons to April 30 this year:—Denmark, 805,970 tons (as compared with 991,224 tons and 991,224 tons); Spain, 705,448 tons (as compared with 706,610 tons and 1,251,119 tons); and Norway, 704,630 tons (as compared with 921,109 tons and 880,543 tons). The value of the coal, coke and patent fuel exported from the United Kingdom to April 30, this year, was 13,760,724*l.*, as compared with 11,873,625*l.* and 16,482,765*l.* respectively.

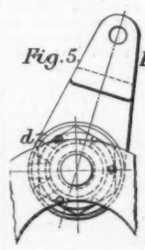
THE KELLY SHELL-MARKING MACHINE.

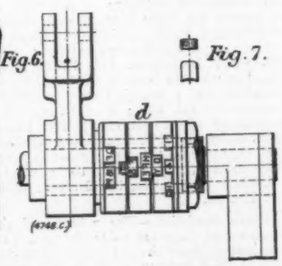
CONSTRUCTED BY MESSRS. JAMES R. KELLY AND CO., LIMITED, ENGINEERS, LEEDS.











We illustrate in Figs. 1 to 7, on the present page, a shell-marking machine built by Messrs. James R. Kelly and Co., Limited, Bridge End, Leeds, for the marking of 13, 15 and 18-pounder shells. It consists of a strong cast-iron body mounted on a cast-iron stand, as shown in Figs. 1 and 2, and bored out for the various shafts; the machine is driven by belting, with a pinion on the end of the pulley shaft, gearing into a spur-wheel. The spur-wheel is fitted with a crank-pin and an adjustable connecting-rod coupled up to a cast-steel rocking lever, this being keyed on to a mild-steel socket, on which are also keyed the marking discs (see Figs. 5 and 6). The socket works on a shaft fitted in the cast-iron body of the machine and supported on the outer end by a cast-steel bridge. The base is planed out to receive a cast-iron box carrying two steel rollers marked *b* and *c*; the box is hinged on the back pin, on which revolves the steel roller *c*, and is fitted, as shown in Fig 2, with an adjustable wedge and hardened steel plate for regulating the depth of the marking. The box is raised and pressure is thus put on the shell by a foot-lever connected to a cam-lever, as shown in Figs. 1 and 2. The marking dies are of hardened steel in separate pieces, which are let into the mild-steel rings *d*, and held together by three screws, as shown in Figs. 5 and 6. The shell to be marked is placed on the machine, the projecting pin *a* entering the nose; the machine is then started running by shifting the belt from the loose to the fast pulley by means of the hand-lever. The operative in charge presses down the foot-lever which is carried on a bracket shown in position in Fig. 1, and somewhat displaced in Fig. 2; this slightly raises the roller *b*, and by contact with the rings *d* fitted with the marking dies the shell is given an oscillating motion, during which the marks are stamped on the shell body. Figs. 1 and 2 show the foot-lever depressed; a set-screw directly underneath and in a line with the cam-lever serves to regulate the upward thrust of the box carrying the two steel rollers *b* and *c* and the pressure of the shell body against the marking rings *d* according to the calibre of the shells to be marked. The capacity of the machine is the marking of four or five shells per minute.

"THE FRENCH EXPORTER."—A journal having this title has been started in Paris. It is to appear in French, in English and in Spanish, and its object is to supply information both to French merchants, and to foreign merchants having business connections with France. Further information can be obtained from the publishers, 24, Boulevard des Italiens, Paris.

ENGINEERING STANDARDS COMMITTEE.—Report No. 75 of the Engineering Standards Committee, dealing with British Standard specifications for wrought steels for automobiles, has just been issued and should prove of considerable value to the automobile industry. Four classes of case-hardening and six classes of stamping steels commonly used in automobile construction are dealt with in the report and are designated "E.S.C." steels. A Research Committee formed jointly by the Institution of Automobile Engineers and the Society of Motor Manufacturers and Traders is proceeding with further investigations into the physical properties of the standard automobile steels and into the factors governing the testing of the same. The Report, No. 75, the price of which is 7s. 10d. post free, may be obtained direct from the offices of the Committee, 28, Victoria-street, Westminster, S.W., and is published for the Committee by Messrs. Crosby Lockwood and Son, of 7, Stationers' Hall Court, E.C.

RUSSIAN METALLURGY.—The production of pig-iron in Russia last year was 3,695,560 tons, or 564,448 tons less than the corresponding output for 1914, and 851,816 tons less than in 1913. Taking no account of Poland, and considering only Southern Russia, the Urals, and the central districts, the output for 1915 was 3,648,344 tons, as compared with 4,003,534 tons in 1914, and 4,135,324 tons in 1913. The output of semi-finished steel last year was 4,018,000 tons.

THE BRITISH CHAMBER OF COMMERCE FOR ITALY.—The British Chamber of Commerce for Italy informs us that sample show-rooms for British goods, with the exhibition show-cases, are now ready. They are situated in a very central position, in a main street of Genoa, and near the Italian Chamber of Commerce, the Exchange, and the principal banks. The rooms are lofty and adapted for the sample exhibition of British goods suitable for import into Italy, now being organised, as originally proposed in 1911. The offices of the Chamber are in the same premises, and all callers will pass through the show-rooms, which it is intended to keep open daily during working days from 10 to 12 a.m. and 2 to 5 p.m. Applications for space will be dealt with as received. Further information can be obtained from Mr. E. B. Weatherhead, Secretary-General, British Chamber of Commerce, 7, Via Carlo Felice, Genoa.

QUADRUPLE-SCREW LINER "LAFAYETTE," OF THE COMPAGNIE GÉNÉRALE TRANSATLANTIQUE.

CONSTRUCTED BY THE SOCIÉTÉ ANONYME DES CHANTIERS ET ATELIERS DE PROVENCE, ENGINEERS, PORT DE BOUC.

(For Description, see Page 470.)

FIG. 11. DINING SALOON.

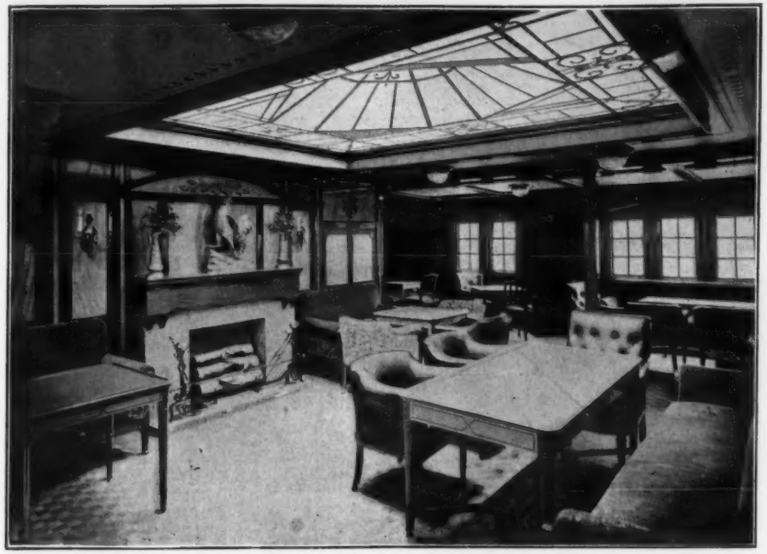


FIG. 12. SMOKING-ROOM.

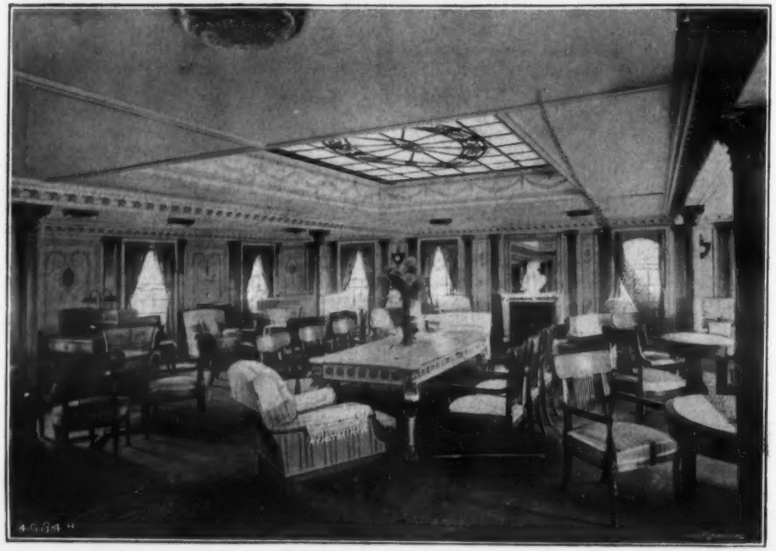


FIG. 13. LADIES' SALOON.

FIG. 14. LOUNGE.

(To face page 471.)

(To face page 471.)

THE QUADRUPLE-SCREW LINER "LA
COMPAGNIE GÉNÉRALE TRANS

CONSTRUCTED BY THE SOCIÉTÉ ANONYME DES CHANTIERS ET ATELIERS D

(For Description, see Page 70.)

Fig.6

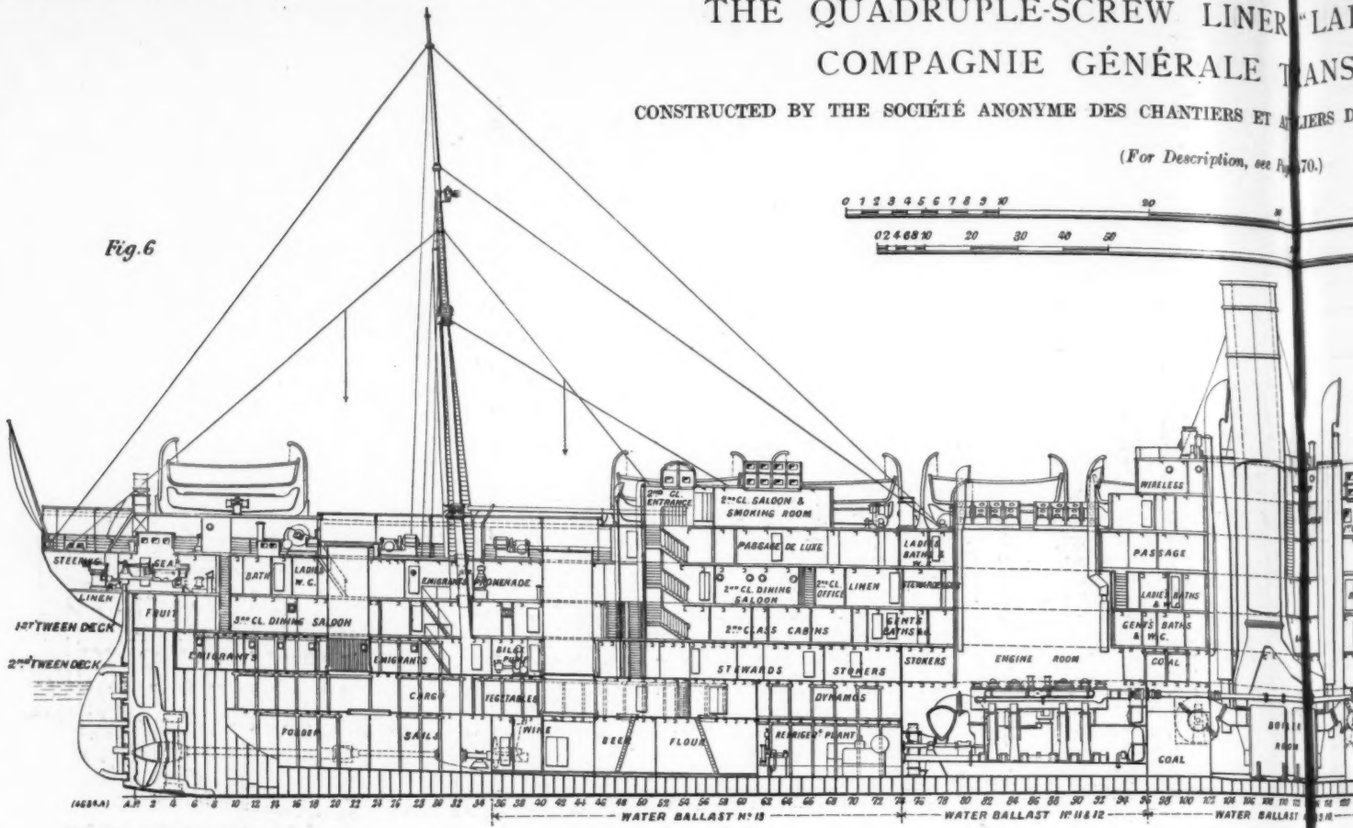


Fig.7. PROMENADE DECK.

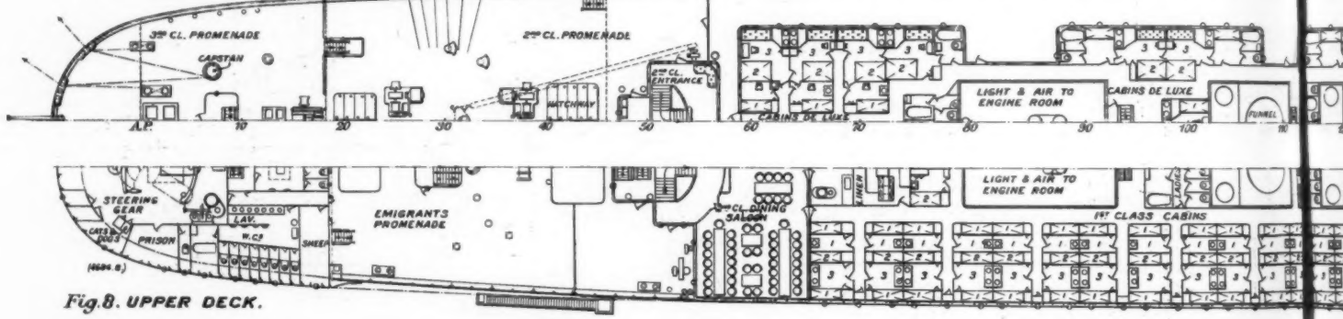


Fig.8. UPPER DECK.

Fig.9. 1ST 'TWEEN DECK.

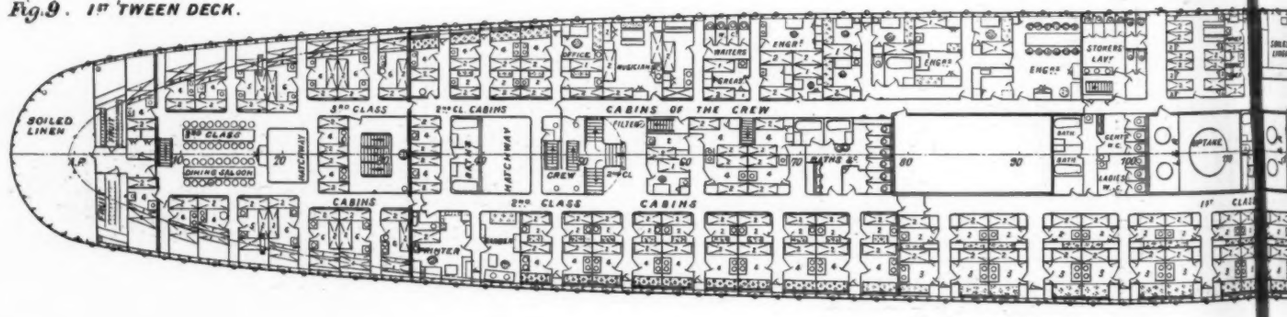
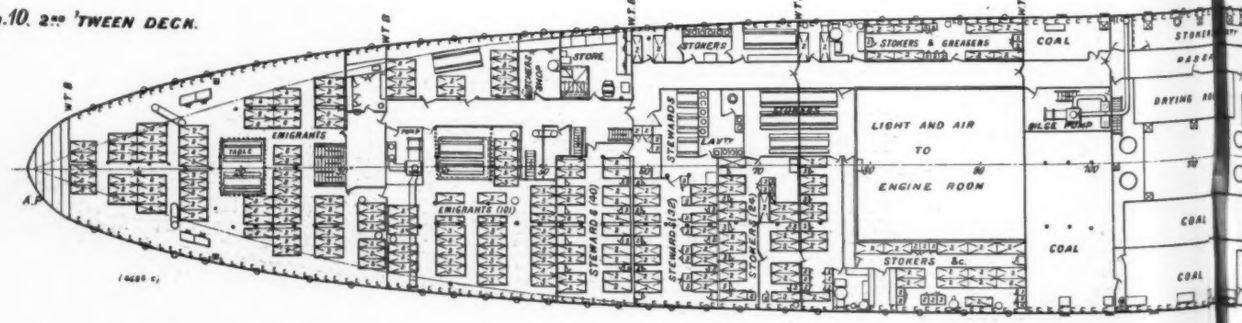


Fig.10. 2ND 'TWEEN DECK.



NER "LAFAYETTE," OF THE
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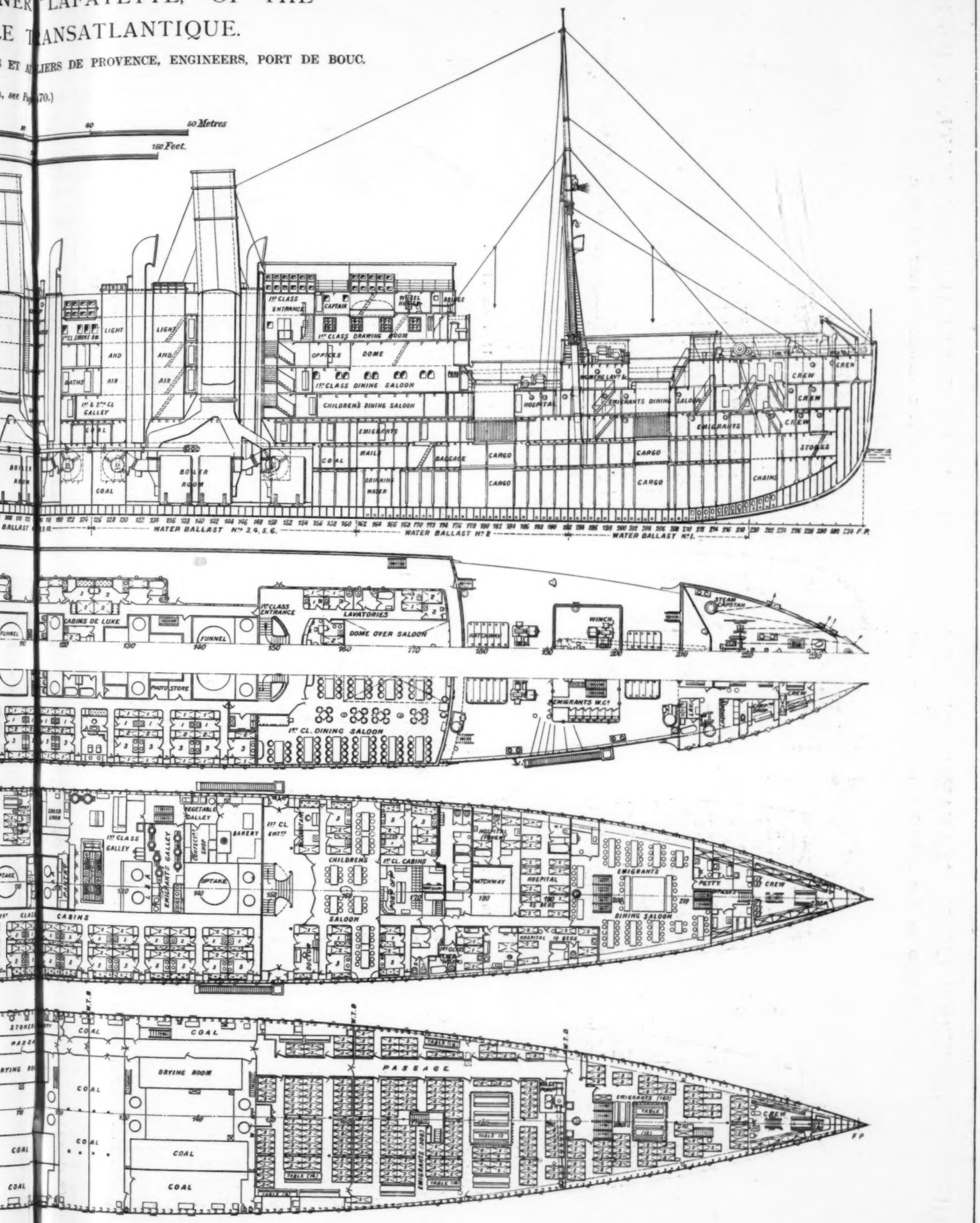


QUADRUPLE-SCREW LINER "LAFAYETTE," OF THE COMPAGNIE GÉNÉRALE TRANSATLANTIQUE.

CONSTRUCTED BY THE SOCIÉTÉ ANONYME DES CHANTIERS ET ATELIERS DE PROVENCE, ENGINEERS, PORT DE BOUC.

(*For Description, see page 470.*)

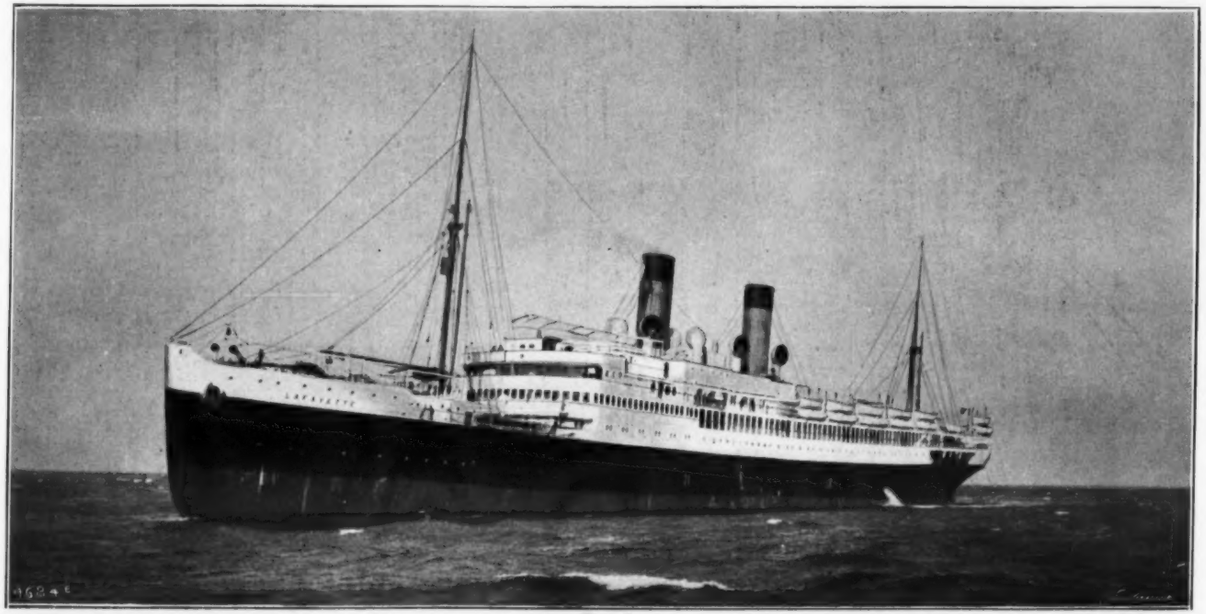


FIG. 1.

Fig. 2. DECK HOUSES & CAPTAINS' BRIDGE.

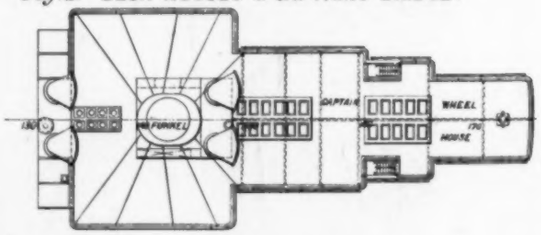


Fig. 3.

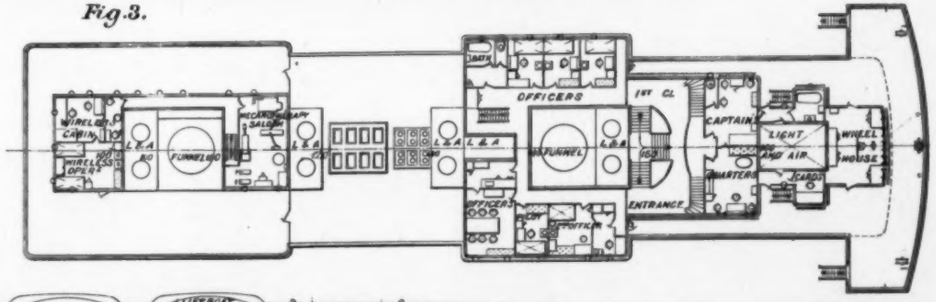


Fig. 4.

ASTERN PLATFORM.

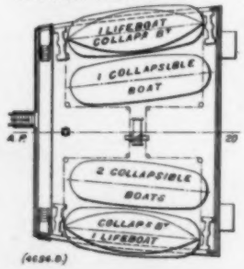
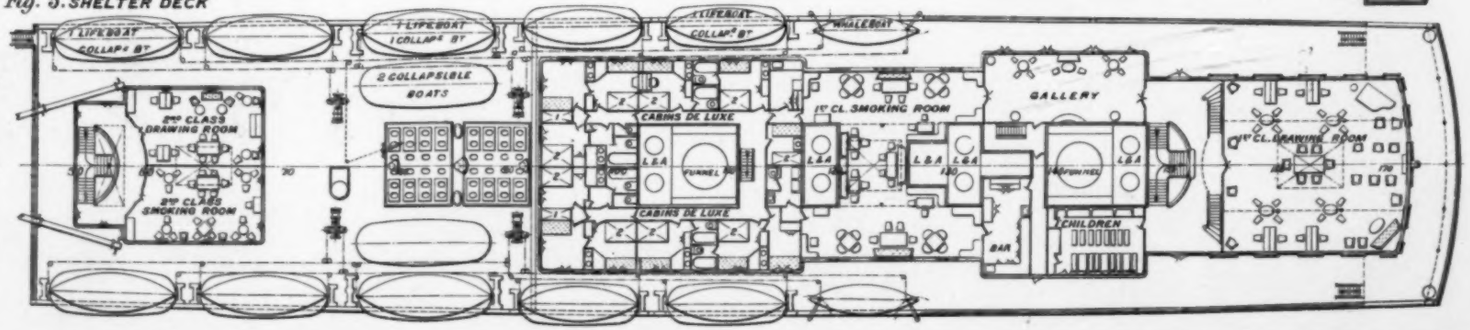


Fig. 5. SHELTER DECK



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Advertisements intended for insertion in the current week's issue must be delivered not later than 5 p.m. on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received not later than 1 p.m. on Tuesday in each week.

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NOTICES OF MEETINGS.

THE INSTITUTION OF MECHANICAL ENGINEERS.—Friday, May 19, at 6 p.m., at the Institution of Civil Engineers, Great George-street, Westminster. Subject of paper: "Spur-Gearing," by Mr. Daniel Adamson, Member.

THE ROYAL SOCIETY OF ARTS.—Monday May 22, at 4.30 p.m., Cantor lecture: "Vibrations, Waves, and Resonance," by Mr. J. Erskine-Murray, D.Sc., F.R.S.E., M.I.E.E. (Lecture IV.). Wednesday, May 24, at 4.30 p.m. Ordinary meeting: "Zinc; Its Production and Industrial Applications" (Peter Le Neve Foster Prize Essay), by Mr. John Collett Moulden, A.R.S.M., M. Inst. M.M., Member of the Australasian and American Institutions of Mining Engineers. Mr. Dugald Clerk, D.Sc., F.R.S., Chairman of the Council of the Society, will preside.

THE INSTITUTION OF MECHANICAL ENGINEERS: MEETING AT MANCHESTER.—Tuesday, May 23, at the Engineers' Club, Albert-square, Manchester, at 7.30 p.m., when a paper on "Spur-Gearing," by Mr. Daniel Adamson, Member, Manchester, will be read and discussed.

THE OPTICAL SOCIETY.—Thursday, May 25, at the Rooms of the Chemical Society, Burlington House, Piccadilly, W., at 8 p.m. The following paper will be read and discussed:—"Sands Used in Glass-Making, with Especial Reference to Optical Glass," by Dr. P. G. H. Boswell.

THE ROYAL INSTITUTION OF GREAT BRITAIN.—Friday, May 26, at 5.30 p.m. A discourse will be delivered by Professor Charles G. Barkla, M.A., D.Sc., F.R.S. The subject is "X-Rays." Afternoon lectures next week at 3 o'clock. Tuesday, May 23. Professor Charles S. Sherrington, M.D., LL.D., D.Sc., F.R.S., Fullerian Professor of Physiology, Royal Institution, on "Unconscious Nerves—their Functions in External Life" (Lecture II.). Thursday, May 25, Sir Alexander Mackenzie, Mus. Doc., D.C.L., LL.D., Principal of the Royal Academy of Music, on "The Beginnings of the Orchestra and its Instrumental Combinations" (Art Illustrations) (Lecture I.). Saturday, May 27. Professor H. S. Foxwell, M.A., F.B.A., Fellow and Director of Economic Studies, St. John's College, Cambridge, on "The Finance of the Great War: How we Stand To-Day, and What Lies Ahead" (Lecture II.).

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions now imposed by the Government on the importation of paper, and of the consequent shortage of supplies, readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk. Owing to the scarcity of paper it will be impossible in future fully to provide for a chance demand for this Journal.

ENGINEERING.

FRIDAY, MAY 19, 1916.

COLLECTIVE EFFORT FOR INCREASED PRODUCTION.

To voluntary effort and a splendidly free competitive system must be attributed in great measure the past successes of this country in the domains of commerce and industry. But a revision of our phrases, with some change in the methods of applying them, is now urgently demanded. Germany's wild endeavour after world-domination, apart from transmitted antagonisms and the war-lust of a section of its people, is the outcome of a belief in the overwhelming superiority of national organisation and the unrestrained desire to make demonstration of that superiority—a form of barbarism in modern guise. Yet there it is, and who can deny that as regards marvellously devised preparation, not merely of material and men for military purposes, but above all, of that national spirit which has expressed itself on the one hand in personal sacrifice, and on the other in ruthless outrage, Germany has shown to the world what a scientifically organised State can accomplish? No doubt Nemesis lies in wait, and in the issue it will be made clear to those mechanicalised and hypnotised German folks that national progress is not to be determined by its readiness for acts of aggression. Meanwhile red ruin and the waste of human life attest the "efficiency" of the Prussian idea.

Little wonder, then, that we should be treated to a flood of exhortation based on the conviction that the voluntary system has penalised the British nation and that the time for unrestricted voluntary action has gone. It is not the question of compulsory military service that is here under consideration. On that subject there is no longer room for doubt. The words refer to the production and, inferentially, to the distribution of wealth. Every thoughtful person experiences alarm when he contemplates the immense destruction of our national resources—accumulated wealth and vast potential energy of brain and body—during the progress of the war, and is still more disturbed when he attempts to estimate the heavy demands of the immediate future. He cannot by any cunning word-play get free from the notion that, of the immense volume of material wealth which has been blown to the winds, or cast into the sea, there can be no real recovery. Hope turns to the possibility of increasing production, and able men are directing their thoughts to problems of management and organisation. To meet, however, the loss of that greatest asset—those young men of the nation, skilled, trained, and of finest quality, who were engaged in industries prior to the war—special endeavours involving changes in our educational outlook must be made. It is instructive to note in this connection that the chairman of the Belfast Association of Engineers (Mr. J. W. Kempster) at its conference on April 27, while advocating co-ordination of effort, or, as it is called, "collective effort," remarked that he "could remember the time when schools were thought to be out of touch with engineers," and he believed that "one thing the war was doing was to bring them a little more in touch with one another." Not an epoch-making phrase this. Yet, as the key-note of Mr. Kempster's address is that "the country which can make a prompt application of labour to available productive purposes would succeed," there can be no question as to his having in his mind the part which the schools of the country, and particularly those engaged in higher-grade and secondary education, must play in preparing our youths to answer at once, and in proper spirit, the call for increased production.

The "collective effort" movement contended for at the Belfast conference, as at the meeting of Manchester engineers and in the Council for the Organisation of Engineering Industries, must therefore include our educational agencies and particularly the operations of the great departments of State responsible for the elementary, secondary, scientific and technical instruction of the youth of the country. Traditional school and college courses, traditional methods of training, and the traditional attitude of schoolmasters are under trial at this time. Change is imperative. It is not that cherished ideals should be hustled overboard, but we must jettison a lot of useless deck-cargo and top-hamper. Education must be re-organised, and adapted to the inevitable needs of the near future. There will be, nay, there is, an urgent call for "labour promptly applicable to productive purposes" in countless directions. To be of highest national service that labour must be earnest, intelligent, efficient and permeated with a sense of responsibility. In helping towards this essential condition for successful "collective effort" the Education Departments and the schoolmasters can discharge a momentous function. On their shoulders lies a duty charged with great consequences.

A few weeks ago there was issued a memorandum, signed by some three dozen eminent scientists, directing attention to the neglect of science in our educational schemes and demanding speedy and drastic action. The staff of the Imperial College of Science and Technology supported the memorandum and quoted Professor Huxley's saying that "everybody is aware that, at this present moment [1887], there is hardly a branch of trade or of commerce which does not depend more or less directly upon some department or other of physical science, which does not involve, for its successful pursuit, reasoning from scientific data." Now it may be doubted whether the relatively small amount of instruction in natural science given in the schools of Germany, or the somewhat classical and philosophic indoctrination of its ruling classes, have had *per se* much to do with German "efficiency." The real influences are to be found in regimentation and specialisation; in fact, in the separate cell system of society, which, according to Dr. Kerschensteiner, secures self-suppression of the individual save in that particular activity in which he is engaged. If, then, this touches truth, the memorandum referred to is defective. Further, it has to be remembered that Dr. Huxley's words fall on good soil, and that in this country, and specially in Scotland, there has been for many years in many of the higher schools most fruitful cultivation of science with due regard to principles and giving full opportunity for essentially practical work. This is not the place to deal with the objections of the classicists to "science in schools." Dr. Rouse, who, after naming Shakespeare, Homer, Thucydides, Cicero and the others, remarks that "we cannot do without the best, or we sell our birthright for a mess of potash," has many sympathisers, and without committing our-

selves to how much of "the best" boys can and must have, we make bold to say that not one of the signatories objected to the humorism. It is not so much in the presence or absence of this or that subject in a school curriculum that help is to be found. We incline to the suggestion of Mr. Kempster's address. We believe that in "collective effort"—*i.e.*, co-operative effort, organised for a purpose, and that purpose national rather than individual—lies the promise of national prosperity. And the schools must do their part. Each youth beyond the elementary stage must be induced to see that the State is educating him not for special individual wins over his fellows, but in order that in realising the best that is in himself he may contribute best to the general good. While his training, in that view, must be as broad and cultural as possible, there should be very definite programmes of preparation for practical life and for his giving "prompt application of labour to some one or other of available productive processes." In arranging wisely detailed schemes with this end in view, the Education Departments can do much in conjunction with representatives of the great industries and with the great associations which exist in this country. As a scheme of secondary education involving something of the nature of apprenticeship for youths over, say, 16 would necessarily run across "use-and-wont," it would be advisable to secure the interest and sympathy of men as well as of masters.

The obstacles in the way of educational reform in the direction indicated are great, but great is the need for able young men for commercial, industrial and agricultural enterprises. If "collective effort" can assume permanently a definite practicable character under the auspices of the State, even as we have it to-day in the munitions and transport services, the possibility and desirability of direct contribution from the schools to such "collective effort" may be assumed. The type of labour would be of great value from its pliability, intelligence and discipline; and the experiences of national service (for that is what their practical work would be) which youths from 16 to 18 might have in fields, factories or workshops, would encourage an attitude of mind of vital consequence to the stability of the State.

GAS ANALYSIS BY FRACTIONAL LIQUEFACTION AND DISTILLATION.

The use of fractional low temperature liquefaction and distillation for analytical purposes has lagged behind the application of such methods for the technical separation of gases. The occasional use of liquid air, which cannot be stored in closed vessels, is wasteful, and liquid air has, for this reason, not yet become a common laboratory material. For certain purposes, however, fractional liquefaction and distillation methods seem alone to be available, and the method of natural gas analysis on these lines, worked out at the United States Bureau of Mines (Technical Paper 104, by G. A. Burrell, F. M. Seibert, I. W. Robertson), renders analyses possible which were so far hardly attempted, and marks an important advance. We have of late noticed several oil-cracking processes the resulting gaseous products of which were simply grouped as gasolines or illuminants, or paraffined hydrocarbons. The results would have been more valuable if the percentages of the individual constituents could have been given; but suitable modes of separation were hardly known.

The new method was worked out in experiments with natural gas and with illuminating gas. The natural gas consisted essentially of methane, ethane, and nitrogen. But "wet" gas escaping from oil-wells may contain a good many hydrocarbons, the most common (and their boiling-points at atmospheric pressure) being: methane (— 160 deg. Cent.), ethane (— 93 deg.), propane (—45 deg.), normal butane (+1 deg.), isobutane (—10 deg. Cent.) &c. In the research 1.5 litres of natural gas was liquefied and submitted to fractional distillation. The gas was charged into a cylindrical bulb, which was connected by a three-way tap with a Topler pump on its one side and with gas-analysis burettes on the other. To condense the gas, a Dewar flask filled with liquid air was raised so as to surround the bulb. When the gas was condensed the pump was worked; the nitrogen and methane then evaporated again, whilst most of the ethane and the other constituents remained liquid. By recondensing the methane, this gas was isolated in fairly pure condition. The liquid air, we should mention, should not be quite freshly prepared (at — 193 deg. Cent.), but be a little stale, so to say, being then practically oxygen boiling at a temperature of about — 183 deg. Cent. The liquid residue was afterwards placed in a less cold bath (not liquid air), so as to effect a separation of the other constituents, some liquid at a temperature of — 140 deg. or — 125 deg. Cent. being wanted for this purpose. Various liquids were tried, alcohol, ether, ethyl chloride, &c.; but they all "jellied"—that is to say, they became too viscous at low temperatures to be stirred, and stirring was necessary to obtain a uniform bath temperature. Finally a good material was found in "wild gasoline"—*i.e.*, the liquid produced by subjecting natural gas (casing-head gas) to a pressure of 250 atmospheres and cooling it, finally by means of liquid air. Why this mixture of butane, propane, &c., should behave more uniformly than ethyl chloride, &c., we do not know; perhaps the former chemicals were not very pure. However, with the aid of this wild gasoline and of several liquefactions and distillations, the ethane, butane, and propane were all separated from one another. The steps were controlled by watching the vapour pressures; while the pump was being worked that pressure would keep fairly constant, until it suddenly dropped nearly to 0; the pump was then stopped, and the liquid allowed to volatilise at rising temperature; a new liquefaction and distillation would subsequently follow.

These experiments, which involved a good many different operations, having been successful, similar experiments were made with a gasoline from West Virginia, which contained the same constituents as the natural gas, but in other proportions, and in addition some hexane and higher homologues. The temperature control was effected by means of pentane thermometers which the Reichsanstalt introduced years ago for low temperature research. Illuminating gas was then treated in the same way, the artificial gas of Pittsburg being selected; it is made by mixing one part of carburetted water-gas with three parts of coal-gas. The further constituents to be considered in this case (again with their boiling-points) were:—Hydrogen (— 253 deg. Cent.), nitrogen (— 195 deg.), oxygen (— 183 deg.), carbon monoxide (— 190 deg.), carbon dioxide (— 80 deg.), ethylene (— 103 deg.), propylene (— 51 deg.), isobutylene (— 4 deg.), and benzol (+ 80 deg. Cent.). These constituents were more or less completely separated by the new method, having recourse also to other expedients. Benzol, *e.g.*, was separately determined, again by a utilisation of the same principle which had been suggested by G. A. Hulett, of the Bureau of Mines, in the first instance, for the moisture determination in air. The apparatus in this case consists of a glass tube provided with a three-way tap, two bulbular extensions, and a branch serving as pressure-gauge. The upper one of the two bulbs is packed with glass-wool and phosphorus pentoxide; the lower bulb is dipped into the cooling bath. Above the tap the tube is joined to a pump. When moist air is to be tested—which is an easy, but rather tedious, operation when the moisture is, in the ordinary way, absorbed by passing large volumes of air through drying-tubes—air is sucked into the lower bulb, which is then placed in a mixture of acetone and solid carbon dioxide (at — 78 deg. Cent.). All the water-vapour having been condensed to ice, the air is withdrawn by means of the pump. The cooling mixture is then removed, and the pressure of the re-evaporated water is measured in the gauge-tube. In this moisture test the packing with phosphorus pentoxide is not required; for the benzol determination it is wanted. The gas is first freed of carbon dioxide; the gas is then introduced into the bulbs, the moisture is absorbed by the phosphorus pentoxide, and the benzol condensed in the lower bulb, the gauge of which records the pressure of the benzol. In this way it was proved, *e.g.*, that 1.3 per cent. of the 8.67 per cent. of "illuminants" otherwise determined in the Pittsburg gas consisted of benzol. The separation of the ethane and ethylene, whose boiling-points are only 10 deg. Cent. apart, could not however, be satisfactorily effected. On the other hand, G. A. Burrell and G. T. Boyd (Technical Paper 115) succeeded in separating gasoline vapour from benzol with the aid of the Hulett tube; the bath in that case consisted of liquid air, not of carbon dioxide. This last-mentioned research concerned the inflammability of mixtures of gasoline vapour and air. They found that the gasoline formed explosive air mixtures within the upper and lower limits of 5.3 and 1.5 or 1.6 per cent. of gasoline; varying conditions, ignition from the top or the bottom, or by sparks of different amperes and volts, affected these figures, but not much; preheating of the gasoline to 400 deg. Cent. reduced the lower limit to 1.02 per cent. The gasoline was of 73 deg. B.; but we do not enter into particulars, as an analysis of the gasoline is not given.

As regards the new method of gas analysis, it will probably take some time to devise suitable and economical apparatus. The wild gasoline above mentioned was poured into a Dewar flask, for instance, and stirred with a test-tube charged with liquid air until the gasoline temperature had fallen to the — 140 deg. Cent. desired. That sounds wasteful. When mechanical and chemical laboratories are equipped with air-liquefaction plants, however, the waste of separate operations will be less serious, and the need for low-temperature research is becoming more and more recognised in many fields.

ON REDUCTION GEARS.

By John H. Macalpine.

(*Continued from page* 457.)

(c) *Rise in the Temperature of the Pinion.*—If the temperature of the pinion or gear, or both, rises above that of the bed-plate, the expansion will cause the designed pitch circles to overlap slightly. This effect is equivalent to moving the centres closer to one another, which produces no error in the action of involute teeth. We need not, therefore, regard further this effect of the rise of temperature.

The pinion is heated slightly more than the gear, principally by the conduction of heat generated in its high-speed bearings, as the frictional loss in the teeth is slight. The heat is carried off by the copious supply of cool oil between the teeth and to a small extent by the air. Before the tests of the experimental gear it was a matter of considerable speculation whether the heating of the pinion would not determine the limiting load which could be transmitted, since expansion of the tooth pitch necessarily relieves the load at one part and thus concentrates it at another. To guard against this, provision was made to pass a stream of cooling water through the pinion. The water-inlet and water-catcher were never fitted, as our fears were found to be groundless. Even at 6000 horse-power and 1500 revolutions per minute of pinion the elevation of pinion temperature above that of the gear, though sensible to the hand, was slight. After each run the teeth were carefully examined to discover hard bearing at those ends where the expansion would cause it, but we found none. This has been quite borne out by all subsequent experience.

No doubt if a bearing was allowed to run very hot there would be cause for some fear, but, happily, with high-speed journals hot bearings are very rare, where the design is correct. So long as the bearing temperature is kept moderate, say not over 160 deg. Fahr., no trouble from expansion of the pinion need be feared. To secure this moderate temperature the supply of oil must be very copious, and to accomplish this:—

1. The oil should be freely supplied through channels at the sides of the bearing, where the pressure of the journal is zero, extending nearly the whole length of the bearing.

2. The babbitt should be scraped away over a considerable arc on each side of these channels, as this helps the free ingress of the oil.

3. The journals, after very careful finishing, may be draw-filed longitudinally with a "smooth" file. This greatly increases the quantity of oil which is

drawn in, thickening the oil film in the bearing and thus diminishing friction, and also carrying off the heat generated much more freely. Draw-filing should only be done by a most experienced workman. Experience has shown that it is not necessary in ordinary cases.

4. The bearings should not be too long, as the means of escape of the heated oil is at the ends. Nor should they usually be shorter than the journal diameter, as endward escape is then too free. The mean pressures may range from 90 lb. or 100 lb. per sq. in. for short journals up to 140 lb. for longer, and it is sufficient to make the centre journal 40 per cent. of the total journal length. This actually gives considerably more intense pressure on the middle journal than on the ends, but, as Fig. 2 (see page 417 *ante*) shows, the pinion lies much better in this bearing than in the others. The foregoing applies to a floating-frame gear. In a rigid gear allowance would have to be made for less even distribution of pressure. In a two-bearing gear with long span, we have seen that the bearings cannot be made very satisfactory.

It has long been known that a high-speed journal is completely oil-borne.* Hence the friction per square inch of journal would be proportional to the rate of shear of the oil film and entirely independent of the pressure, if the thickness of the film and viscosity of the oil were constant. Doubling the length of a bearing will halve the mean intensity of pressure and thus allow the oil film to become a little thicker, but it will also double the area of shear and greatly hamper the end flow of the heated oil. Thus, lengthening a high-speed bearing too much may make it run hotter. Also, it has been found that, at constant speed, increase of load does not cause much rise of temperature, for the oil film is little diminished in thickness and the rise of temperature diminishes viscosity. Nor is the rise of temperature with increased speed so great as might be expected, for then oil is carried in more freely, causing the oil film to thicken and preventing the rate of shear rising in proportion to the speed. In all respects Professor Osborne Reynolds's theory agrees most accurately with the observed facts.

The heating of the pinion expands both the longitudinal and circumferential pitch of the teeth. Let us consider the former first. As Fig. 3 (see page 456 *ante*) is drawn, that is, with H_1, the helix next the driving end A, right-handed, and the direction of rotation left-handed, when looking from that end, expansion of the longitudinal pitch will relieve the tooth pressure or open the contact towards a and a' and concentrate it towards b and b'. This is best, since we have found that torsion has the reverse effect, opening the contact at b and, if there is a floating frame, at b'. Thus the two effects partially counteract one another. If the direction of rotation is reversed, the handing of the helices would also have to be reversed to produce this effect.

Due to the heating, let the pitches of the gear and pinion teeth be changed from equality to a ratio of $1 : 1 + \tau$. This changes $a\,b = h$ to $h \times (1 + \tau)$, giving a *longitudinal* opening of contact at a and $a' = h\ \tau$. Measured along the pitch circle this is $h\ \tau \tan \theta$, where θ is the helical angle of the teeth at the pitch surface.

In the rigid gears θ is very frequently made 45 deg. to make the gear run more quietly; the above value then becomes

$$h\ \tau.$$

In gears with floating frames the helical angle has always been made 30 deg. The reason for fixing on this value will be stated later. The above opening of contact then becomes

$$0.577\ h\ \tau.$$

The error is also diminished by keeping the helix length h down.

In Fig. 5 we have a section normal to the axes of the gear and pinion, showing an arc of contact of about two pitches. There are three contacts, α, β, γ, and the distance $\alpha\ \gamma$ in the pinion will be expanded by $(\alpha\ \gamma)\ \tau$, giving this opening of contact at γ to be added to the larger value $h\ \tau \tan \theta$ due to longitudinal expansion It seems very possible that this does not need to be fully taken into account. For if in hobbing the teeth an exact involute is formed along a section normal to the tooth, it can be shown that the section normal to the axis, shown in Fig. 5, will not be an exact involute, but will be slightly too much cut away at the point. The effect increases as the ratio of pitch to diameter increases, so that while it is quite sensible in the pinion, it is very small in the gear. This would relieve the hard pressure brought on at a by expansion. Nevertheless, it may be of interest to note that, whether from slight error in the form of the teeth, or expansion, the points of the pinion-teeth of the experimental gear showed evidence of hard bearing and were slightly filed down. It is improbable, however, that this was due to expansion, as it was particularly noticeable at both ends of each helix and to a less extent all along.

(*d*) *Errors of Alignment.*—In the experimental gear, just outside of the bearings of the journals, J_1, J_3, it was arranged that gauges could be fitted —though this was never done—to gauge the adjustment of the gear and pinion axes at any time, even with the gear running. The distance from centre to centre of the gauge-holes is 9 ft. 4½ in., the bearings being made longer in the experimental gear than the present practice of the Westinghouse Machine Company. Suppose that the pinion is held in rigid bearings, the axes of gear and pinion being designed to be horizontal and, of course, parallel. Let all be in exact adjustment except that the pinion-gauges show a difference of level e, J_1, being higher than J_3. This error may be supposed to be produced by a slight rotation of the pinion from its correct position, round a horizontal axis through a, Fig. 4. The contact at a will be closed and, by a slight rotation of the pinion about its axis and displacement to the left, that at b' also. The contacts at b and a' will be open. The measure of this opening along the pitch line is

$$\frac{h\ e}{112.5} \quad . \quad . \quad . \quad . \quad . \quad (8)$$

Let us again take $\frac{1}{1000}$ in. as the limit of opening of contact which the elasticity of the teeth will close without too greatly upsetting the distribution of tooth pressure. (This quantity should, of course, be chosen larger or smaller according as we find the allowable average pressure greater or smaller; that is, it will vary with the value of the power constant found practical for any type of gear.)

If $h = 20$ in., the allowable value of e is given by

$$\frac{20\ e}{112.5} = \frac{1}{1000} \text{ or } e = \frac{112.5}{20 \times 1000} = 0{\cdot}0056 \text{ in.}$$

This is an exceedingly fine adjustment. Of course, by trial, bedding of the pinion and scraping of the bearings till the teeth show red-lead marking all along, this adjustment can be made. But the slightest inequality of spring of the bearings when the load comes on, the slightest unequal wear of the bearings vertically or horizontally, the loosening of a holding-down bolt of the gear housing, the heating of a bearing, in a marine installation the grounding of the hull at a point near the gear, will readily cause a much greater error than the above. This error is shown by the dotted line A C, Fig. 6.

Similarly, a horizontal error of alignment will cause point contact. When everything is in exact adjustment suppose the pinion slightly displaced by rotation about a vertical axis E F, Fig. 5, passing through a', Fig. 4, such that the point a recedes from the gear axis. The contacts at a' and b will be closed and those at b' and a opened; but from Fig. 5 it is obvious that the amount will be proportional to tan ϕ where ϕ is the angle of obliquity of the teeth in the section normal to the axis. Neglecting the curvature of the teeth the expression for the opening of contacts is

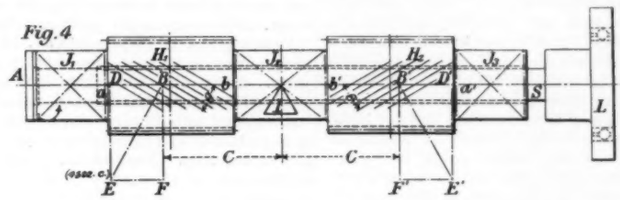
$$\frac{h\ e' \tan \phi}{112.5} \quad . \quad . \quad . \quad . \quad . \quad (9)$$

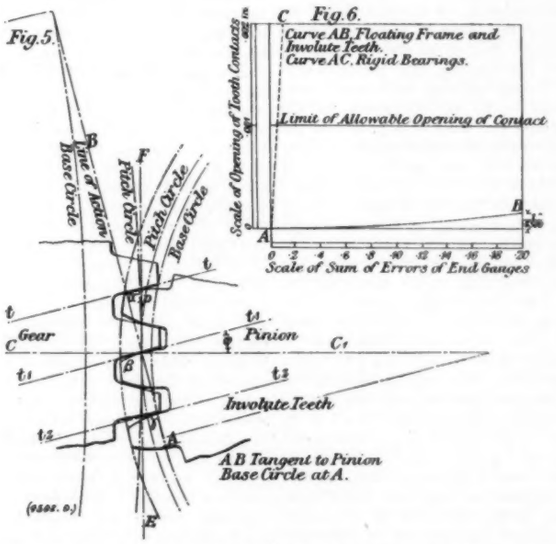
where e' is the total gauge error. Comparison of expressions (8) and (9) show that for $\phi = 14$ deg. 30 min. a vertical error is about four times (tan 14 deg. 30 min. = 0.2586) as serious as the same value of horizontal error, and for $\phi = 18$ deg. 30 min. about three times as serious.

The vertical error supposed opened the contacts at b and a', and the horizontal error opened them at a and b'. Hence, if we combine these in the proportion

$$\frac{\text{Vertical rotation}}{\text{Horizontal rotation}} = \tan \phi,$$

all contacts would be opened by the same amount and a slight rotation about the pinion axis would close them all.





C
Fig. 6.
Curve AB, Floating Frame and Involute Teeth.
Curve AC, Rigid Bearings.
Limit of Allowable Opening of Contact
Scale of Opening of Tooth Contacts
B
A
0 2 4 6 8 10 12 14 16 18 20
Scale of Sum of Errors of End Gauges

* See Mr. Beauchamp Tower's "Experiments on the Friction of a Journal" (Transactions of the Institution of Mechanical Engineers, London, 1883 and 1885), and Professor Osborne Reynolds's "Theoretical Analysis of these Experiments" (Philosophical Transactions, Royal Society, London, 1886).

This is evident from Fig. 5. For the combination of these rotations would be equivalent to a single rotation about A B, the line of action of the teeth, which is inclined to the vertical at the angle ϕ.

This is precisely what the floating frame accomplishes. If there is an error in the vertical plane only, opening the contacts at b and a', the resultant forces B E, B′ E′ are displaced from the centre of the helices towards the left, and they at once bring back the pinion into correct adjustment, closing all contacts. A similar action takes place if the vertical error opens the contacts at a and b'. Thus an error in the vertical plane cannot exist alone, and all that is required is to set the pinion axis in the same vertical plane as the gear axis.

Similarly, a horizontal error cannot exist alone, as it would either open the contacts at a and b', moving B E, B′ E′ to the right, or it would open the contacts at a' and b, moving B E, B′ E′ to the left. In both cases the tooth pressures would again rotate the floating frame about the horizontal axis till the moments of these forces about I were zero, as in Fig. 4. Thus the floating frame determines that the only rotation of the pinion axis from perfect adjustment must be about A B, Fig. 5

If we could neglect the curvature of the teeth, all contacts would evidently remain closed after rotation about A B, as the teeth of the gear and pinion would then be represented by their common tangents $t\,a\,t$, $t_1\beta t_1$, $t_2\gamma t_2$, which are parallel, as they are always normal to A B. As we may neglect this curvature for an infinitely small displacement, the curve A B, Fig. 6, is tangent to the zero line at A. To trace the effect of a finite error let us suppose it introduced by a rotation about an axis A B, Fig. 5, passing through I, Fig. 4. The linear movements of a and a' will be greater than those of b and b', as the former are farther from the axis of rotation. If we suppose the contacts at b and b' kept closed, the curvature of the teeth at these points would determine the exact movement. The radius of curvature of the movement of a particle at a would then be increased from that at b as I a: I b, and similarly for that at a'. That is, the points of the pinion at a and a' would follow a flatter curve than that which would keep the contacts perfectly closed. The calculation involves several steps, and it would serve no purpose to trouble the reader with it. The result for the experimental gear, taking $\phi = 14$ deg. 30 min.,* is shown by A B, Fig. 6, the opening of contact for a horizontal gauge error of $\frac{1}{5}$ in. being $\frac{1}{85\frac{1}{00}}$ in. It varies as the square of the gauge error, so that for $\frac{1}{10}$ in. error it is $\frac{1}{2500}$; that is, it does not exist, and, within errors so large that they could never occur by accident or wear, the floating frame gear should run perfectly as a skew-bevel gear.

In erecting the experimental gear the final gauging made just outside the points a and a_1, about 5 ft. 9 in. apart, showed a horizontal error of $\frac{1}{80}$ in., or $\frac{1}{30}$ in. gauge error. As the device was of no value unless it would run out of line by this amount, which we could easily have corrected, I ordered the holes in the I-beams for the fitted bolts to be reamed, and all trials were run in this condition, the action being perfect.

To allow the pinion axis to shift freely it is driven by the turbine through a loose coupling, one-half of which is shown at L, Fig. 4, and a flexible shaft S passing through the pinion-shaft.

With involute teeth there is, as we all know, no error introduced by setting the gear and pinion centres a little closer or wider than designed, if the axes remain parallel; that is, the velocity ratio remains constant. If set too close, the backlash will be taken away and the teeth will jam; if too wide, the arc of contact will become unduly restricted, the tooth pressure per inch will become too intense, and severer cross-bending stresses will be set up in the teeth. But there is a sensible range within which the distance of centres may be altered. Hence the horizontal error is the only one which must be guarded against in a floating-frame gear. This may occur through wrong setting, as was deliberately done with the experimental gear. If not, it can only be produced by *unequal* side wear of the brasses. Now, in high-speed bearings with their protective oil film of appreciable thickness, wear is practically insensible in almost all cases; as the forces are much more nearly vertical than horizontal, rate of vertical wear will be several times that of side wear, and the brass should be nearly worn out before side wear is serious; finally the *difference* of rate of side wear in journals J_1, J_2, J_3, should be an infinitesimal fraction of the total side wear. Hence we may conclude that, if once set correctly, the alignment of the pinion will remain correct far within allowable limits.

We see how simple the correct lining of the pinion is compared with that for a rigid gear where the machining and final bedding of the pinion in the bed-plate must leave its axis exactly parallel to the gear axis. Also, any accidental distortion of the bed-plate which would cause intense concentration of tooth pressure in a rigid gear, and possible disaster, would not sensibly affect the distribution of pressure where there is a floating frame.

There is one minor but interesting and not insensible source of error in rigid gears which I have not noticed. I am unwilling to pass it over, as it shows with what great accuracy the floating frame avoids the effect of error of alignment of the axes. If the axes are exactly aligned, all the particles of the gear and pinion in the normal section, Fig. 5, revolve in one plane. But if, as above, misalignment is produced by rotating the pinion about any axis—say E F—we will now have non-planar rotation. It would make no difference in the result if we supposed the section, Fig. 5, and the axis E F to occupy different longitudinal positions in the pinion, as the only change would then be that the rotation about E F would be accompanied by a slight approach or parting of the gear and pinion centres at this section, such as is allowable with involute teeth; neither would it matter if E F did not pass through β, as that would only superpose a longitudinal shift of the whole pinion. For simplicity let E F be in the plane of the section. The slight rotation about E F will either cause the contact point a in the pinion to rise above or sink below the plane of the paper, and γ to move in the reverse direction. If $a\,p$ is the distance of a from E F, its longitudinal movement is $a\,p \times \lambda$, where λ is the angular displacement about E F. With the straight teeth of spur-gears this would only cause the pinion tooth to slide longitudinally on the gear tooth; but with helical teeth it will either open the contact or bring the teeth hard together, according to the direction of the longitudinal movement and handing of the helices. The effect is greater the longer $a\,p$, and is therefore more serious for other axes than E F. It is very sensible for errors of alignment which may readily occur with rigid gears. It becomes specially important for short spiral gears supported by bearings not far separated, for which a small linear shift of the bearings produces a relatively large angular shift. It would be of the highest importance if the error of alignment is such as Fig. 6 indicates may be allowed to occur with floating-frame gears, but for these the axis of rotation always is A B, and for this axis alone the effect of non-planar rotation is zero.

One other cause of misalignment must be noticed. It is quite simple to machine three bearings in exact line by using a stiff boring-bar and any slight error is corrected by bedding. But take the case of a rigid gear, one bush of each bearing being set in the bed-plate and the other in a cap. If a bearing heats, the bed-plate in the neighbourhood will also be heated and expand, and that bearing will be pushed out of line. The difficulty was carefully considered in designing the floating frame, and to obviate it in the vertical plane the upper and lower halves were made symmetrical about the pinion axis, as shown by the published design, except as to the supporting feet. If a high-speed bearing heats, the freely circulating oil will cause the top bush to rise about as much in temperature as the lower one. The heat being conducted to the symmetrical upper and lower halves will cause both to expand and there will be no warping in the vertical plane.

The floating frame could not be made symmetrical in plan, but it was attempted to allow equally free conduction to the parts nearer the gear axis as to those farther away, and thus make warping in plan no more than a differential effect.

The effectiveness of this feature of the design was unintentionally put to the test. By misjudgment, part of the piping of the oil system was of wrought steel. It was treated in an acid bath to remove the scale as well as possible, but this was not quite effective. On September 27, 1909, while running a trial at about 1500 revolutions per minute and 5000 horse-power, the pinion bearing next the turbine, which we called the forward bearing, heated, probably due to scale finding its way in with the oil. Being anxious to see whether the floating frame would keep straight, as I hoped and believed, I let the bearing get very hot, sending out much smoke, before giving the order to shut down. The entry in my diary may be of interest: "Examination, on September 27, of the forward pinion bearing showed the babbitt flaked off in parts. From the fact that the markings had occurred both near the forward and aft end of the bearing, and at both sides and bottom at each end, it is certain that the floating frame has not bent due to the heat. The babbitt of this bearing was a little loose at the sides." The bearings were re-scraped, the pinion re-bedded, the babbitt pinned down and given more freedom at the sides, and the steel pipes replaced by brass, after which there was no trouble.

The question at once arises whether the alignment of the pinion and floating frame is stable, or whether a slight horizontal error of alignment will tend to increase. When all is in correct adjustment the tooth pressures, neglecting friction, all act along A B, Fig. 5, and the ratio of the horizontal component to the vertical is tan ϕ. Hence, as the moments of the vertical forces are zero about I, those of the horizontal forces must be zero also, and there is no tendency to turn the floating frame. If, as before, we suppose a slight rotation about an axis A B, Fig. 5, passing through I, Fig. 4, the gear and pinion centres at b', say, will move apart, and those at b will approach. If, in Fig. 5, the centres move apart, the inclination ϕ of A B will increase, which also increases the horizontal component of the tooth pressure. Similarly, at those points where the centres approach, the horizontal components diminish. The resultant will be an unbalanced moment in the horizontal plane tending to increase the displacement; that is, with involute teeth the horizontal alignment of the pinion is unstable. To supply this stability beyond question, struts are applied, as explained in ENGINEERING, vol. lxxxviii., page 379. These have an adjusting and locking mechanism, so that at any time the pinion may be lined up to gauge.

(To be continued.)

* Fig. 5 shows the teeth as designed for this gear. I found after the gear was built that the gear-cutters had made the hob with an angle of obliquity of 14 deg. 30 min. so that this value in a section normal to the pinion axis was a little greater. There was no object in repeating the calculation as the opening of contact at B, Fig. 6, was so far within allowable limits.

NOTES.

CHANGEABLE LINES IN THE ARC SPECTRUM OF IRON.

THE International Solar Union resolved in 1910 to establish a system of iron normals based upon the red spectrum line of cadmium; the wave-lengths were to be determined by the interferometer, and the measurements to be made by Fabry and Buisson, Eversheim, and Pfund. Since then spectroscopic tables have been published according to the International Normals. But doubts have arisen as to the constancy of the positions of some iron lines. Eversheim differed from Fabry and Buisson as to certain ultra-violet iron lines by 0.03 Angström unit, and F. Goos found that long arcs and short arcs did not always give the same wave-lengths in the visible spectrum; he observed differences of 0.04 Angström unit. Working under H. Kayser at Bonn, Joseph Lang has recently studied these discrepancies with short arcs (2 mm. to 4 mm. in length) and long arcs (9 mm. to 16 mm.), the electrodes of wrought iron being from 8 mm. to 10 mm. in diameter, the amperes varying between 3 and 15, and the volts between 60 and 440. The short arcs were horizontal, but the long arcs would not keep steady unless vertical. The second-order spectrum

of a large Roland grating was photographed on Schleussner or on orthochromatic plates. The ranges investigated were those studied by Goos and by Eversheim—viz., 5360 to 5660 Angström units (green-yellow), and 2400 to 3330 A (ultra-violet). The accounts published by Lang (Dissertation, Bonn, 1914, and *Zeitschrift fur Wissenschaftliche Photographie und Photochemie*, vol. xv., pages 223 to 252, 1915) show that the wave-lengths of a large number of visible iron lines change with the length of arc, the intensity of the current, and the position of the slit, which was in different experiments near the anode or cathode of the arc. The discrepancies may not be real displacements, and merely be due to an unsymmetrical broadening of the lines. But that explanation does not seem to suffice to account for the magnitudes of the apparent displacements, which would not be explained by pressure fluctuations either. Some of the lines in the ultra-violet proved even more changeable as to position than the green-yellow lines, the displacements being sometimes to the red end and sometimes to the other end of the spectrum; occasionally the spectrum from the positive portion of the arc hardly resembled that from the negative at first glance. But there was a lack of sharpness in the unsteady lines, and reversals of the lines (with distinct or indistinct absorption bands in the lines) were frequent, so that an unsymmetrical broadening of certain lines (not all of them) might, after all, adequately describe the phenomena; the reversals were particularly marked near the negative pole of the arc at high current intensities. An explanation of the variability of the lines is not given; as regards the ultra-violet, Lang picks out certain lines as unsuitable to serve as normals; with respect to the greenish-yellow part of the spectrum the selection of some other element in the place of iron would probably be preferable.

THE ELECTRONIC CHARGE.

While himself advocating the use of the minimum free electric charge, the electronic e, as unit of electricity, F. Ehrenhaft, of Vienna, conducted experiments in 1910 with electrically dispersed metals—gold, silver, mercury, &c.—which seemed to suggest that this charge of the electron was not really the smallest quantity of electricity capable of free existence. By Bredig's method he formed an arc between two electrodes of the same metal in an atmosphere of an indifferent gas (carbon dioxide, nitrogen, &c.), and he observed particles, for which he suggested the name "sub-electrons," apparently carrying less than the assumed electronic charge, down to one-twelfth of it. Out of these statements arose a heated controversy, during which R. A. Millikan and Harvey Fletcher redetermined the e, and found the value 4.78×10^{-10}, electrostatic unit, which was 2 per cent. less than the previous value. The controversy has recently been renewed in the *Physical Review* and the *Physikalische Zeitschrift*. The measurements are made on particles falling by gravity or rising or falling between the plates of a condenser in an electric field; the very fine particles are also subject to Brownian movements, and the equation for Brownian movements therefore come into the calculations, in addition to Stokes' law. Ehrenhaft, moreover, made use of the ultra-microscope, and he maintained that his smallest mercury spherules would keep of constant mass for, say, half an hour, though under strong illumination, without any loss by evaporation or friction with the surrounding gas. This latter statement in particular has been attacked by A. Schidlof, of Geneva, who, in conjunction with D. Targonsky, maintains further that there are important differences in the behaviours of mechanically and of electrically-dispersed particles; they experimented with mercury and oil, and the promised detailed account of their experiments in the *Archives des Sciences* has not yet appeared. They state that with mechanical dispersion the minimum electric charge is 4.68×10^{-10}, and is independent of the size of the particles, while their mobility increases as the radius decreases; with electrical particles, on the other hand, both the charge and the Brownian mobility are said to diminish as the radius is reduced. Fletcher adheres to his value of the electron charge, to which Zerner had objected that the equations for the Brownian movements gave too low values, whilst Schrödinger and Smoluchowski independently propose similar changes in the formulæ. Again, Ehrenhaft has been supported by A. Konstantinowsky, who claims to have measured or estimated charges as small as 9×10^{-12}. Another difficulty of these determinations has been discussed: those finest particles would act as condensation nuclei.

LITERATURE.

The Navy League Annual. Edited by ROBERT YERBURGH, assisted by ARCHIBALD HURD and GERARD FIENNES. London: John Murray, Albemarle-street, W. [Price 5s. net.]

THE war is the dominant topic of all the contributions to this, the eighth, annual volume, and because of the war the usual tables of dimensions, &c., of ships are incomplete and therefore unreliable. The need for secrecy affects also the freedom of the writers in making deductions except on broad lines. But when all this has been said, not by way of disparagement, but rather as indicative of editorial limitation, the issue of the Annual, as usual, must be commended and a study of the articles recommended to all. The war is a long business, and long views must be taken alike in studying the situation and preparing for continued action. Day by day we have encouraging reports from our land forces, the cumulative effect being confidence in the final issue. With the Navy all is silence except for an occasional lifting of the veil, often, alas, to announce some disaster of greater or less consequence. But while silent, the pressure of the Navy is still very heavy, its work of the highest efficiency, and its influence on final victory paramount. The writings in this Annual establish that view, and ought, therefore, to be studied.

Many times a week the question is asked "What is the Navy doing?" The function of maintaining "command of the sea" is not understood or such question would not be asked. Lord Sydenham and Mr. Hurd have thus done well to elucidate this question, the former in his article on "The Influence of the British Navy upon the Course of the War," and the latter in his contribution on "The Triumph of Sea Power." Lord Sydenham says the energy displayed by the Navy and the completeness of the results appear startling. "In less than eight months sea power accomplished more than was achieved until six years after the decisive victory of Trafalgar." To quote again from the article on "The Collapse of German Naval Speculation," by Mr. Hector C. Bywater, who has special knowledge of the Kaiser's naval policy, "The Germanic Empires, with a total population of more than 120,000,000, are, for all practical purposes, as isolated from the sea as Switzerland." This may be a somewhat exaggerated view, but it is nearly the case, and we hope will soon be. Certainly Germany's naval aspirations have been thoroughly defeated. Tirpitz "gave an absolute guarantee that compliance with his demands would render German sea trade and the colonies immune from serious molestation in any contingency." The resultant big navy "has not moved a finger to avert the ruin of Germany's maritime trade, which contributed upwards of 60 per cent. to the total revenue of the Empire." As to the so-called German blockade, "Food, raw material, and munitions of war continue to flow freely into British and other Allied ports. Shipping goes on almost literally 'as usual.' Neutrals, paying no heed to what they now know to be Germany's empty threats, ply between their ports and ours almost oblivious of the fact that their course takes them right through what was long ago announced in Berlin, with much theatrical pomp, as the 'war zone.'" Speculation as to whether the German fleet will make the grand sortie in the hope of justifying the expenditure upon it would be idle; it may be made as a last desperate throw of the dice.

It was a happy idea to get from accredited quasi-official writers in France, Russia, Italy and Japan articles dealing respectively with the work in the war of the navies of these Allies. We are apt to neglect their part, which has throughout been most effective, although in most cases lacking spectacular effects. The ships of those Allies, even when they were not side by side with others, carried out operations which, as the French writer aptly and correctly states, "formed only the different parts of the same plan, and all their forces, even when they appeared separate, were united in the same thought, animated with the same spirit, and were working with one accord at the common task in view, of the triumph of right and of civilisation." Fully justified, indeed, is the hope expressed by Mr. Yerburgh in his foreword—that those sections of the body politic, whose attitude towards the maintenance of our sea supremacy was always critical and frequently destructive, may be led to perceive in the future that the foundations of our island freedom and Imperial stability were founded upon, and must always be sustained by, our unassailable strength upon the sea.

There are also articles on the United States Navy, foreign navies, aircraft and naval engineering—the last almost entirely on the personal element, which has shone so brightly. All official documents relating to the Royal Navy issued in connection with the war are reproduced and add to the value of the Annual.

BOOKS RECEIVED.

Year-Book of Scientific and Learned Societies: A Record of the Work done in Science, Literature, and Art during the Session 1914–15. Thirty-second annual issue. London: Charles Griffin and Co., Limited. [Price 7s. 6d. net.]

The Excess Profits Duty and Profits of Controlled Establishments. By SPICER AND PEGLER, Chartered Accountants. London: H. Foulks, Lynch and Co. [Price 6s. net.]

Pratt and Redman's Income-Tax Law. By the late J. TIDD PRATT, Q.C. Ninth edition. By JOSEPH HAWORTH REDMAN, Barrister-at-Law. London: Butterworth and Co. and Shaw and Sons.

Napier Tercentenary Memorial Volume. Edited by CARGILL GILSTON KNOTT. London: Published for the Royal Society of Edinburgh by Longmans, Green and Co. [Price 21s. net.]

The Athenæum Subject-Index to Periodicals, 1915. *Science and Technology, with Special Reference to the War in Its Technological Aspects.* London: The *Athenæum*. [Price 2s. 6d. net.]

The Motor Transport Year-Book and Directory. Vol. I., 1916. London: Electrical Press, Limited. [Price 10s. 6d. net.]

The Universal Electrical Directory (J. A. Berly's), containing a complete record of all the industries directly or indirectly connected with Electricity and Magnetism, and the Names and Addresses of Manufacturers in Great Britain, India, the Colonies, America, the Continent, &c. A.—British and Colonial Section only. B.—British and Colonial with Continental and U.S.A. Sections. London: H. Alabaster, Gatehouse and Co. [Price 21s. post free. A. Edition 12s. post free.]

The "Shipping World" Year-Book: A Desk Manual in Trade, Commerce, and Navigation. Edited by EVAN ROWLAND JONES. With new Map of the World, specially prepared by J. G. BARTHOLOMEW, F.R.G.S., 1916. London: The *Shipping World* Offices, Arundel-street, W.C. [Price 10s.]

Government of India: the Patent Office. Patent Office Hand-Book (Acts, Rules, and Instructions). Calcutta: Government Printing Office. [Price 1 rupee.]

Liverpool Shipping, 1916: *A Complete Directory, Personal and Official, to the Shipping and Allied Trades in the Ports of Liverpool and Manchester.* Liverpool, London, and Glasgow: The *Journal of Commerce*. [Post free 1s. 3d.]

Work and Wages: The Reward of Labour and the Cost of Work. Founded on the Experiences of the late Mr. Brassey. By EARL BRASSEY, G.C.B. London, New York, Bombay, Calcutta and Madras: Longmans, Green and Co. [Price 3s. 6d. net.]

The Deposits of the Useful Minerals and Rocks: Their Origin, Form, and Content. By PROF. DR. F. BEYSCHLAG, PROF. J. H. L. VOGT, and PROF. DR. P. KRUSCH. Translated by S. J. TRUSCOTT. Volume II. London: Macmillan & Co., Ltd. [Price 20s. net.]

A System of Physical Chemistry. By WILLIAM C. MCC. LEWIS, M.A., D.Sc. Edited by SIR WM. RAMSEY, K.C.B., F.R.S. Volume I. *Kinetic Theory*; Volume II. *Thermo-dynamics and Statistical Mechanics.* London, New York, Bombay, Calcutta and Madras: Longmans, Green and Co. [Price of each volume 9s. net.]

The Munition Workers' Handbook: a Guide for Persons taking up Munition Work. With a Special Chapter on Shell Turning. By ERNEST PULL. London: Crosby Lockwood and Sons. [Price 2s. 6d. net.]

The Institution of Gas Engineers: Transactions, 1915. Edited by WALTER T. DUNN, F.C.I.S., Secretary. London: E. and F. N. Spon, Limited.

JAPANESE ENTERPRISE.—A new steel merger and a further expansion of steel and other plants are reported to be under consideration in Japan; the proposed capital is 10,000,000*l*. A large shipyard is being established in conjunction with the Yokohama Dockyard Company; the capital required is about 350,000*l*. The Pacific service being now largely in the hands of Japanese steamship companies, their representatives have been in conference at Tokio in order to extend and strengthen the service both now and after the war.

"ON THE WHIRLING SPEEDS OF LOADED SHAFTS."

TO THE EDITOR OF ENGINEERING.

SIR,—In your issue of April 7, Mr. Kerr replies at some length to my letter which appeared on March 31. The point at issue is the validity of his fundamental assumption that the load on the horizontal shaft at any point rotates round the unstrained position of the shaft axis or straight line joining the bearings. This assumption I hold to be erroneous. I do not intend repeating the arguments I advanced in my letter in support of my views, but to make the matter clearer and prevent misconception I would supplement them as briefly as I can.

The question is one that can easily be put to the proof. A length of light and flexible shafting with a heavy pulley at its middle point—so as to get an easily observed deflection—rotated smoothly and uniformly between bearings, will demonstrate the truth of his fundamental hypothesis, or the reverse.

But Mr. Kerr admits the plausibility of the argument that rotation takes place about the gravitationally deflected position of the axis in the case of very slowly-moving shafts. At what speed will the change to rotation about the straight line joining the bearings occur, if at all?

Stodola has shown that the shaft remains deflected at speeds far in excess of the first whirling speed. Reference may be made with advantage to Stodola's "Steam-Turbine," English Edition, 1905, pages 365 to 370. There Stodola determines what he calls the "critical velocity of the second degree, caused by the deflection of a uniform shaft, due to its own weight." After some preliminary explanation, he says, "if this velocity is exceeded, the fibre is forced into a too high oscillation, so that it has no time to expand sufficiently, and the shaft, for this reason, straightens out more and more." He shows how to determine this critical speed of the second degree, which for the 250-kw. shaft is about 127,000 revolutions per minute, according to Stodola's equation. The influence of the inertia of the load is then considered; and Stodola concludes "this velocity also lies, in general, very much above the critical velocity. It therefore follows that the critical number of revolutions of the second degree need not be considered in practical problems, and that the designer need not search for its presence, because under certain circumstances the shaft behaved unsatisfactorily."

It thus appears that the speed above which a tendency commences for the shaft axis to assume a less deflected form is a long way in excess of the whirling speed of the shaft—viz., 2500 revolutions per minute.

But even if at such very high speed the shaft axis became less deflected than when in the static gravitational position, it may, I think, very fairly be argued that the flexural rigidity has been virtually increased to a proportionate extent, so that the action of gravity on the load is balanced by the elastic forces consequent on the smaller deformation of the shaft axis. Thus the gravitational potential term in the equations of energy would still disappear.

But we are not concerned here with nearly so high a speed, so I need not develop this point.

I think, therefore, it is clear that the assumption of the rotation of the shaft about the zero elastic strain axis at the speeds in question is untenable.

Now the mathematics cannot be expected to produce a trustworthy result if the underlying hypotheses on which it is based are incorrect. If reliable results are to be obtained it is necessary to express the physical facts correctly in the equations of motion. It is, of course, immaterial what origin of co-ordinate axes is chosen for the determination of the motion; but it is absolutely essential that the physical bases of the problem be correctly introduced. If the axis of rotation of any particular load is assumed to be the zero strain line when in fact it is not, and the forces corresponding to such assumption introduced, the result must be expected to be in error. The methods of Dr. Chree, Professor Dunkerley, and others agree in the critical speeds to which they lead, although their resulting equations give what Mr. Kerr calls a "negative result." For this latter reason he objects to my correction of his work, bringing it into line with accepted theory. The fact that the new speed he obtained is not given by the accepted theory does not prove this theory to be erroneous.

Now Mr. Kerr endeavours to justify his results by saying that the two particular turbines he tested show vibrations that correspond to his new speed. I am not satisfied that the great range of vibrations he has observed can be fully explained by the two individual speeds he has deduced. But there are many other experimental results more definite as regards bearing conditions and loading, such as those of Dunkerley, Stodola, and others which support very satisfactorily the accepted theory and do not give any indication of Mr. Kerr's new critical condition.

In short, these definite experimental results go to show that Mr. Kerr's new deduction is not borne out by facts, save in the particular cases of his own experiments, and these I do not consider conclusive.

In one part of his letter (top of page 321) Mr. Kerr states that it would suffice for the study of the motion to "consider the shaft as vibrating about the deflected position with gravity absent." It will be seen that the amendment I have introduced is tantamount to this. Indeed, if in his paper Mr. Kerr had accepted this view that he now puts forward—that the motion may be determined about the deflected position with gravity absent—he would not have arrived at the result to which I took exception. There would have been no need for amendment, for the gravity-potential term would not then have been introduced at all. Thus he appears here to be in agreement with the accepted theory which leads to the rejection of the new term from his final solution.

While I thus confirm the accepted theory of the calculation of speed involving critical instability, it should be kept clearly in mind that two distinct phenomena may be involved:—(1) Critical or whirling speeds in which *instability* occurs due to equality of righting and displacing forces, and (2) resonance.

Now, according to Dr. Chree's results, resonance may occur at *any* speed whatever, provided an external rythmic action of appropriate frequency be introduced. In fact, if n be the frequency of transverse vibration of the rotating shaft, k the frequency when not rotating, and p the speed frequency, Chree has shown that $n^2 = k^2 - p^2$. A likely frequency at which to expect such external action is the frequency of rotation of the shaft, so that resonance may, under favourable conditions, occur then—but not critical instability.

Other frequencies may also be thought likely, such as every half revolution or other number of revolutions, depending on the shaft connections and nature of drive in any particular case.

One further point worthy of consideration. There is a possibility of resonance in the supports. If a horizontal section through the bearings be considered, the latter experience from an unbalanced shaft forces acting in opposite directions every half revolution. The supports may resonate with this at a suitable speed, even though the speed be not critical or otherwise dangerous. Mr. Kerr has referred in his article to the serious vibration set up throughout the whole college building.

With regard to the suggested explanation I put forward—looseness of bearings—Mr. Kerr has kindly worked out graphically the whirling speed corresponding to an internodal distance of 52.8 in., and finds the figure is higher than in my rough estimate. Presumably, therefore, the speed 2500 corresponds to a length somewhat greater than this, say about 54 in. My suggestion then is that possibly the bearing looseness may permit the vibrations to start at this extreme internodal distance.

Fig. 1 in my letter (page 297 *ante*) was only intended to be diagrammatic, with a view to elucidating my meaning. I hope it served this purpose reasonably well. It should not be regarded as a scale drawing.

At the end of his letter Mr. Kerr asks for the amendments to his alternative solution in Appendix A, where the force equations are used. I had not thought it necessary to give them. Here is the working:—

Referring to the diagram, Fig. 11, amended in my letter (page 297 *ante*), the radial accelerating forces are as given by Mr. Kerr on page 246, viz.:—

$$\frac{W}{g}\,\omega^2\,(m + e) - \frac{W}{g}\,.\,\ddot{m}$$

The radial components of the external forces are—

$$e\,v\cos H\,S\,G - W\sin\omega\,t.$$

But

$$v\cos H\,S\,G = q\sin\omega\,t - m \text{ and } e\,q = W.$$

Hence the radial components of the external forces are equal to $-e\,m$.

Thus the equation of motion becomes—

$$\ddot{m} + m\left(\frac{e\,g}{W} - \omega^2\right) = \omega^2\,e,$$

which should replace Mr. Kerr's equation (a'), page 246. The value of m is therefore the same as given in my letter.

I trust that these remarks, coupled with the explanations in my letter in your issue of March 31, will make my meaning quite clear.

I am, Sir, yours very truly,

Dublin, April 14, 1916. H. H. JEFFCOTT.

PERFOMANCE OF BRITISH WESTINGHOUSE TURBINES.

TABLE I.—RUNNING STATISTICS OF NO. 1 TURBINE. PORT DUNDAS.

Date.	Duration of Period.	Units Generated. Total Output of Station.	Proportion Generated by No. 1 Turbine.	Percentage of Total Output of Station.	Percentage of Possible Output of Turbine.	Average Load. Kw.	Hours Run. Possible.	Actual.	Percentage of Possible.
February 3, 1914, to July 23, 1914	5 months and 20 days	25,511,089	10,125,400	39.6	41.12	5300	4,104	1910.75	46.6
July 24, 1914 to February 10, 1915	6 months and 17 days	35,933,557	22,646,100	63.0	77.85	5465	4,848	4144.75	85.5
February 11, 1915, to October 31, 1915	8 months and 20 days	48,944,089	30,206,400	61.7	79.76	5540	6,312	5450.0	86.3
July 24, 1914, to October 31, 1915	15 months and 6 days	84,877,646	52,852,500	62.2	78.93	5510	11,160	9594.75	85.9

WE publish herewith some data showing the results obtained in service with two turbines recently constructed by the British Westinghouse Company, of Trafford Park, Manchester.

The first table, above, gives the running statistics of a turbine installed in the Port Dundas power-station of the Glasgow Corporation. This turbine, which is of the Westinghouse-Rateau high-pressure impulse type, is rated at 6000 kw., and runs at a speed of 1500 revolutions per minute. The alternator generates 3 phase current at 25 periods 6600 volts, and can take an overload of 25 per cent. for two hours and 50 per cent. for half an hour. This unit is complete with direct-coupled exciter. At the present moment there is in course of manufacture another 6000 kw. set, together with surface-condensing plant, which will be to all intents and purposes a duplicate of the set above described.

The second table gives particulars of the running of a 300-kw. mixed-pressure D.C. turbine, which is also in service in the Glasgow district. This turbine is of the Westinghouse - Rateau mixed - pressure impulse type, rated at 300 kw. and runs at a speed of 3000 revolutions per minute. The generator develops full load at 460 volts and is of the three-wire type. The commutator is of the well-known radial type, the design of which enables sparkless commutation to be obtained at all loads at high speeds. The condensing plant is of the multiple jet type, working in conjunction with a natural-draught cooling-tower.

TABLE II.—300-*Kw. Mixed-Pressure Direct-Current Turbine Installed in the Glasgow District.*

Date.	Hours in Service. Possible Hours.	Actual Hours.	Hours Off.	Mean Kw.	Maximum Kw.	Remarks.
July–Dec., 1910	4,380	4,142	238	80	150	
Jan.–Dec., 1911	8,760	8,482	278	85	155	
Jan.–Dec., 1912	8,784	8,704	80	94	165	
Jan.–Dec., 1913	8,760	8,672	88	115	185	
Jan.–Dec., 1914	8,760	8,411	349	170	240	230 hours due to damaged impeller.
Jan.–Dec., 1915	8,760	8,612	148	207	273	66 hours due to grinding commutator, &c.
Total ...	48,204	47,023	1181	—	—	—

Spare plant consists of two belt-driven dynamos with a total output of approximately 100 kw.

"THEORY AND PRACTICE IN THE FILTRATION OF WATER."

TO THE EDITOR OF ENGINEERING.

SIR,—At the close of the meeting of the Institution of Mechanical Engineers, held on April 14, the President invited any of those present who had been unable to take part in the discussion on my paper on "Theory and Practice in the Filtration of Water" to send in written communications for publication, with the author's reply thereto, in the Proceedings. Several gentlemen have responded to this invitation and will comply with the regulations of the Institution by regarding their communications as the property of the Council until they are published in the Journal.

Mr. William Paterson sent in a communication which in its original form was identical with a letter addressed by him to the Press and which you publish in your issue of the 12th inst. I certainly think it is due to the author that criticisms of any paper read before the Institution should only be published with the paper itself and with the author's reply to the discussion. I understand also that the Council reserves the right to edit all matter sent in for publication in the Proceedings, so that errors in quotations from a paper or remarks not germane to the subject under discussion may be corrected or deleted.

As you have published the paper in full your readers will be able to form their own opinion of it, and I would have preferred to wait for the publication of the discussion in the Proceedings before replying, but for the fact that your correspondent's remarks require correction in important particulars.

Mr. Paterson's opinion on the Cawnpore installation may be taken for what it is worth, but so far as I am aware, it has not been invited by the Government of the United Provinces.

Mr. Paterson visited Cawnpore in January, 1914, at a time when the raw water for the filters was being drawn from a canal, owing to reconstruction of the pumping machinery at the Ganges intake and other local causes. What he saw therefore was not the "fine silt of the Ganges," and the best answer to his statement that this "penetrates the finest filtering medium and coagulation is necessary to effect its removal," is to be found in a recently issued Government report which I have before me, and which states that no coagulant has been used since multiple filtration was adopted, while

the following quotation from the report is a complete refutation of Mr. Paterson's statements regarding the Cawnpore installation: "*There is very little doubt that the new plant gives a safer water than under the old system and provides greater flexibility as regards the final filters, and that the actual maintenance charges are less with the new plant than they would have been had the extension been carried out under the old system.*"

The tables in my paper referred to by Mr. Paterson do not show that the water discharged by the final sand filters contains a larger amount of matter in *suspension* than when it entered. The tables quoted give the results of tests for "total solids," and I assumed that anyone familiar with water supply would be aware that a laboratory test for total solids must always include solids in solution as well as solids in suspension.

The two analyses quoted by Mr. Paterson are by Dr. Rideal and Dr. Hanbury Hankin respectively, and both these well-known authorities are aware of the harmless nature of the matter dissolved out of the sand beds at Cawnpore and other places where Ganges sand is used.

Mr. Paterson admits the correctness of my contention that rapid filtration alone cannot effect purification, but must be assisted by coagulation, sedimentation and sterilisation, but he does not say how these are to effect reduction of organic matters in solution in a polluted water, and his selection of the case of Poonah as an illustration of the advantages of rapid filtration (assisted by coagulation, sedimentation and sterilisation) is not altogether a happy one.

From the fact that the raw water is said to contain about 1,000,000 *fæcal* bacteria per c.c., it may be inferred that the intake is situated at no great distance from a sewer. After coagulation and sedimentation the water is to be passed through a rapid filter, which, *even if* it effects 99.9 per cent. bacterial purification, may still leave 1000 *dangerous* bacteria in the *filtered* water.

The last line of defence against these is presumably to be sterilisation by ozone or ultra-violet light, and, except in case of a breakdown, the dangerous bacteria may be destroyed. But dangerous bacteria can only exist in the presence of organic matter, and after coagulation and sedimentation and rapid filtration, this must be in solution. Mr. Paterson does not explain how this organic matter, which is of the same origin as the fæcal bacteria, is to be got rid of, as the nitro-bacteria, which alone can reduce the organic matter in solution, will be destroyed, together with the 1000 dangerous bacteria, during sterilisation of the *filtered* water.

Yours faithfully,

Shortlands, May 16, 1916. WALTER CLEMENCE.

To the Editor of Engineering.

SIR,—Having read the letter from Mr. William Paterson which you published in your issue of the 12th inst., I am unable to agree with the criticisms of the writer on Mr. Walter Clemence's paper on the above subject.

I was present at the meeting of the Institution of Mechanical Engineers on April 14, when the paper was read and discussed, and having since carefully read the paper as published by you, I may say that I do not gather from the author's carefully reasoned statements the impression which Mr. Paterson's criticism conveys. The paper had evidently been prepared with great care and appears to me to form a valuable contribution to the literature on the subject of filtration.

As Mr. Paterson is a member of the Institution, it would surely have been preferable, and more in accordance with the spirit of scientific investigation, that he should have sent his contribution to the discussion for publication in the Proceedings with the paper, where it could be read side by side with the author's reply, rather than to open a discussion in the Press before the publication of the report of the meeting at which the paper was presented has been concluded in the Journal of the Institution.

Yours faithfully,

H. B. B.

REINFORCED CONCRETE REGULATIONS; STRESS ON STEEL.

To the Editor of Engineering.

SIR,—There is an old saying "that an ounce of practice is worth a pound of theory;" this may be far-fetched, but not so far-fetched as the hard-and-fast regulations of the L.C.C. relating to the stress on steel bars for reinforcing concrete, in which all classes of steel bars are treated on the same basis and not allowed a higher stress than 16,000 lb. to the sq. in., a limit that has been established and which is perfectly appropriate for ordinary plain mild-steel bars of 28 to 32 tons tensile strength, but is clearly inapplicable to bars having special properties, including a much higher yield point and ultimate strength.

The R.I.B.A. formula previously permitted a stress of 20,000 lb. to the sq. in. on bars so long as the minimum yield point was 40,000 lb. to the sq. in. and the ultimate strength not less than 80,000 lb. Now the new L.C.C. regulations—which will no doubt be copied by other councils framing reinforced concrete regulations—state that no steel shall be stressed beyond 16,000 lb. to the sq. in. The effect of this will be to entirely kill competition between patent or special steel-bar manufacturers and plain round-bar manufacturers, as it will entirely shut the former out of the market, unless they become designers to obtain their business.

I have been nearly five years engaged on the work of convincing engineers and designers that it is as safe to stress a certain patent bar, of which I am the inventor, to 20,000 lb. as it is to stress plain round bars to 16,000 lb.; in fact, I claim it is safer. In a great measure I have been successful and considerable business has resulted, many thousands of tons having been sold during the last four years, the steel in many cases being stressed from 20,000 to 22,000 lb. to the sq. in. without failure.

If the above-mentioned regulations of the L.C.C. should be generally adopted, all our labours will have been in vain, and the company of which I am a director must either shut up or become designers to sell our steel bars, whereas we previously sold them on merit. Designers and engineers will be fearful of exceeding a 16,000 lb. stress, although many of them admit it is quite safe to do so; should a failure take place the authorities will possibly attribute the cause of the failure to the higher stress put on the steel.

It is now universally admitted by the highest authorities that the yield point of a steel bar is the absolute limit of resistance in reinforced-concrete structures; the ultimate strength is never reached, as the concrete has failed as soon as the steel starts to yield.

I give below an illustration of the difference between a 16,000 lb. stress to the sq. in. on a plain mild-steel bar having a minimum yield point of 32,000 lb. to the sq. in. with an ultimate strength of 62,720 lb. (28 tons) and a special high tensile bar stressed to 20,000 lb. to the sq. in. and having a minimum yield point of 55,000 lb. to the sq. in., with an ultimate strength of 80,000 lb. to the sq. in.

I will take as an example a plain round bar having an area of 1 sq. in., which, when stressed to 16,000 lb. to the sq. in., has another 16,000 lb. left to the yield point, or a safety factor of 2. The safety margin between the stress of 16,000 lb. on the bar and the ultimate strength is 46,720 lb., or not quite 4 to the ultimate.

A stress of 20,000 lb. to the sq. in. on a special high tensile bar, to carry the same actual calculated stress of 16,000 lb., would need a bar with an area of 0.8 of a sq. in.; this bar would actually have a yield point of 44,000 lb. and an ultimate strength of 64,000 lb., the difference between the stress on the bar and the yield point being 28,000 lb., or 12,000 lb. more than is the case with the plain bar stressed to only 16,000 lb., whilst the difference between the calculated stress on the bar and the ultimate strength is 48,000 lb. still higher than that in the case of the plain bar.

Surely then it is as safe to use higher stress of 20,000 lb. to the sq. in. on the 55,000 lb. yield point steel as it is to use 16,000 lb. to the sq. in. on the 32,000 lb. yield point steel, especially when the higher yield point steel has a slight mechanical bond as an extra safeguard beyond the ordinary adhesive bond. Is it wise that such unnecessary restrictions should be placed in the way of British engineering industry, especially in such times as we now live in, when there is absolute need for economy and every ounce of steel is required? It seems like shutting the door on national requirements and improvements.

Yours faithfully,

ARTHUR W. C. SHELF.

LABOUR EXCHANGES AND TECHNICAL STAFF APPOINTMENTS.

To the Editor of Engineering.

SIR,—I am of the same opinion as "Two Interested Engineers" *re* the engaging of technical staff through the labour exchanges. I am by no means convinced that the possible value of any applicant's services can be assessed in this manner as efficiently as by normal methods of advertising. Further, I would extend the lists they give down the scale to foremen.

The clause "no person on Government work will be considered" is too strictly adhered to. Can any good purpose be served by refusing to consider any applicant whose services would be placed to greater advantage and value in another direction? While some regulation is needed to produce definite outputs, I ask why is the same regulation applied to prevent output in another direction? It stands to reason that firms must be requiring staff, otherwise they would not advertise for them, and unless they get the right man their ouput must suffer. I will state one case I know. Some while ago it was publicly stated that great difficulty was being found in producing a certain class of munitions, and about the same time a gentleman was offered a post in this class of work. His past experience was exactly that which would be necessary in the class of work I refer to. Further, I consider his experience was being wasted in his present capacity, and it would have been a fairly easy matter to replace him. His application to leave was sharply turned down. The net result is a direct loss to the country generally of this man's experience and a personal loss to himself of a salary 25 per cent. at least in excess of what he was receiving. I personally know where foremen have to supervise and take responsibility of work and draw a salary (subject to income tax) considerably less than charge-hands and workmen under them. What can they do? If they try to better themselves they are at once claimed as indispensable, and the clause I refer to above prevents them placing their services in more pleasant conditions. Can the best results be obtained—and at present we only want the very best results—under these conditions?

My opinion is that the staffing of works engaged upon munition work should be done by a special department of the Ministry of Munitions and not left to local exchange managers. The essential qualifications of those engaged in this department to be that they are engineers in a position to assess the value of applicant's experience and suitability for the post under consideration. This, so far as I can see, is the only way to replace normal advertising methods, if these have to be replaced and certain restrictions imposed.

I am, Sir, yours truly,

ANOTHER INTERESTED ENGINEER.

DIESEL-ENGINE USERS' ASSOCIATION.

AT the May meeting of this Association Mr. R. L. Quertier, B.Sc., A.M.I.C.E., London manager of Messrs. Reavell and Co., Limited, made some remarks on behalf of his firm, who are the makers of the air-compressor which failed at the Smithfield Diesel engine plant, as reported on page 333 *ante*. He thought that the abnormal conditions shown by the examination of the compressor after the accident were confined to the high-pressure suction and delivery valves, which were exceedingly badly carbonised, and to the relief-valve on the intermediate purge-pot, which, when tested after repair, only blew off freely at about 380 lb. per sq. in. This relief-valve was set by the makers to blow off at about 275 lb. per sq. in., so that it must have been readjusted by screwing up the spring to the limit. The accident occurred almost immediately on starting up after the engine had been out of service for some hours; the temperature of the compressor was, therefore, very much lower than normal, and it would seem that the conditions were not at all favourable for an explosion to take place. There seemed no doubt, however, that an explosion did occur, since a calculation of the strength of the purge-pot showed that the bursting pressure would be in the neighbourhood of 2300 lb. per sq. in., and since it was broken into fragments, these facts did not point to a fracture at the weakest section, which one would expect with a steadily increasing load, even if that were rapidly applied. Assuming, therefore, that an explosion occurred, his firm's theory was as follows:—The high-pressure valves were not acting, with the result that there was more or less open passage connection between the final delivery pipe to the blast-bottle and the intermediate purge-pot. The valve between the blast-bottle and the compressor was opened just before the accident, and this would allow the dense air in the blast-bottle to rush back along the pipes to the intermediate purge-pot by way of the high-pressure cylinder. They suggested that the velocity at which the rush took place and the density of air caused it to carry away any oil deposited on the pipes and to churn this into a fog. The intermediate relief-valve is capable of dealing with all the air aspired by the compressor with a rise in pressure of not more than 30 lb. per sq. in.; but it was obviously incapable of dealing with an almost instantaneous rush of air from the blast-bottle, and consequently the pressure rose till a balance was obtained. All the while the intermediate cylinder was delivering air, and had now to compress against this greatly increased pressure, so that the temperature of the delivered air rapidly increased till it was sufficiently hot to ignite the oil mist in the purge-pot and cooling-pipes. It was not necessary for this rush back of air to take place immediately the blast-bottle valve was opened, because the compressor was at work and the conditions necessary—i.e., a more or less free passage into the I.P. purge-pot and coils—may not have been immediately present. The same conditions would be obtained with a slower leak back if for any reason the I.P. relief-valve was not in its proper working order. If this theory be the correct explanation of the explosion, it was clear that the greatest possible safeguard would be a back-pressure valve inserted in the final delivery pipe between the blast-bottle valve and compressor. Mr. Quertier thought that this valve should be fitted close to the blast-bottle end of the pipe, as there the air pulsation would be less definite and the air would be cooler. These conditions would ensure the valve working freely without undue wear or tendency to stick. Quite apart from the accident above referred to, he thought it was clear that no undue rise in temperature could occur in the compressor, even if either or both the high-pressure valves failed, if in the first place the air in the blast-bottle were prevented from rushing back by the above-mentioned check-valve; and, secondly, if the intermediate pressure relief-valve were kept in proper working condition, so that it would prevent the I.P. delivery pressure rising, by blowing off all the air aspired by the compressor with the reasonable rise in pressure for which the relief-valve was designed.

THE UNITED STATES NAVY.—We read in the *Moniteur de la Flotte* that the United States submarine L1 has completed her trials satisfactorily. The L1 is the largest American submarine. Her length is 52 m. (170 ft. 7 in.); her stem is shaped like the fore-part of a surface vessel. The propelling machinery consists of Diesel engines. There are four torpedo-launching tubes located forward.

YOKOHAMA.—Work is proceeding on Yokohama pier, which is being reconstructed and which, when completed, will be 400 yards long, with a width of 30 yards. It will be constructed to allow of the passage of automobiles and carriages, and will accommodate at one time four ocean steamers of 12,000 tons. At present the largest ocean steamers lie out at anchor, as the Customs quays have not sufficient depth of water for them to lie alongside. The native population of Yokohama at the close of 1914 was 410,765. Foreign residents and Chinese numbered 6992; the number of British residents was 1314. The number of steamers which entered the port of Yokohama in 1914 was 1192, of an aggregate burthen of 3,961,999 tons; the corresponding entrances in 1913 were 1382 steamers, of an aggregate burthen of 1,796,378 tons. A hammer-headed crane has been erected in the new Customs enclosure at Yokohama; it is of the latest type, is 94 ft. in height, and can lift 50 tons. An analysis of the trade of Yokohama in 1914 exhibited the annexed results:—United States, 44 per cent.; British Empire, 22 per cent.; China, 10 per cent.; France, 6 per cent.; Germany, 4 per cent.; and other countries, 14 per cent. The trade of the British Empire with Yokohama in 1914 amounted to 10,268,640*l.*, as compared with 12,581,703*l.* in 1913.

THE INDUSTRIAL SITUATION IN BELGIUM.

THE industrial exchanges in Brussels and Charleroi appear to be fairly well attended, especially by representatives of the coal-mining industry. There have been frequent complaints about the shortage of rolling-stock, but of late matters have mended in this respect, and transport both by rail and by canal has become more efficient. The state of the coal-mining industry is on the whole pronounced to be good, especially as regards gas coal, as the gas-works are endeavouring to replenish their stocks. A lively demand for industrial coke has caused the price to rise 2 francs, and several coking plants which have been lying idle for a considerable time are now again being started. The principal demand comes from the neutral countries, especially Holland and Sweden, also Switzerland and Luxemburg. Of the home industries it is especially the glass industry which is in need of fuel. The production within the different coal-mining districts varies a great deal; in the Charleroi mines work generally goes on from three to six days a week, in the Borinage district five days a week, and in the central districts there are no extra shifts. The reports of the coal-mining concerns for 1915, which have now been published, mention in some instances a slowly-increasing production during the first months of the present year. The production of coal during 1915 amounted to 14,240,000 tons, against 22,800,000 tons in 1913; whereas the production of coke only amounted to 484,000 tons, against 3,400,000 tons in time of peace. The production of briquettes had receded from 2,600,000 tons in 1913 to 1,200,000 tons in 1915. Boring work has been going on in the coal deposits which form a continuation in a southern direction of the Mons coal basin, near the French frontier, and coal has been reached at different depths—396, 466, 619, and 628 metres. This work was started before the war broke out, but has only recently been proceeded with. The demands for concessions comprise some 13,720 hectares (33,500 acres), but the applications seem to clash with claims made by older concerns. A large capital will in any case be needed owing to the nature of the deposits, and some years will probably have to pass before rational working can commence in earnest. The new Campine coal-basin gives better promise; coal from borings 500 metres deep appears to be well suited for coking. Similar qualities have hitherto only been found in the Mons district, and the new deposits are not unlikely to prove of some importance for Belgian industry.

The iron industry continues to suffer from lack of orders, and most works are only being kept going in order to maintain the plant in good condition and to give the men some employment. Only a few blast-furnaces are being fully worked, and these principally for the manufacture of foundry iron of somewhat common quality. From want of raw material the production of steel is very limited; in many cases the works have to fall back upon scrap, and for some months there were regular quotations for such material, but latterly the market has become very unreliable.

The zinc industry has a reduced production, and is mostly confined to working up the ore found in the country. The manufacturers of machine-tools and machinery have in some instances begun to manufacture to stock and to complete their plant. Some of the engine and wagon works have resumed, under compulsory German management, on the repair of locomotives and railway carriages. The electrical industry, from lack of raw materials, is almost completely idle, and the same applies to the textile industry. Some of the cement factories are beginning work again, and in the enamelled ware industry, the centre of which is the district of Charleroi, employment is improving. The motor-car industry has not yet resumed its full activity. It is not improbable that the Belgian automobile industry, which, in spite of not paying particularly well, had a considerable capacity and enjoyed a world reputation, will be less favourably situated after the war on account of the altered industrial conditions.

In the glass industry 12 factories are at present working, and a further resumption of work, which was expected some months ago, has several times been interrupted. The increased cost of raw material and other expenses has resulted in a considerable rise in the price for manufactured glass, ranging from 80 to 100 per cent. Rational working at the glass works has only recently been possible. An almost general strike within this branch on account of wages disputes necessitated lengthy negotiations, with the result that the men obtained an advance of 10 per cent.; some 4000 hands getting work, but in times of peace some 35,000 hands are employed in the Belgian glass industry. At present the export, which is confined to neutral countries, absorbs about 60 per cent. of the production.

As the Belgian industry was based to such a great extent upon export, which is now so seriously impeded, and as there is no question of manufacturing war material, its position, naturally, is difficult.

TRADE OF NEW SOUTH WALES.—The oversea imports during January were valued at 2,526,881*l.*, and show an increase of 168,000*l.*, or 7 per cent., as compared with the corresponding month of last year. The total for the seven months July to January was 19,157,518*l.*, an increase of 1,907,681*l.*, or 11 per cent., in comparison with the figures for 1914–15. The oversea exports for January amounted to 2,402,033*l.*, being an increase of 391,838*l.*, or 19.4 per cent., as compared with the corresponding month of last year. For the seven months July to January there was an increase of 10,198,903*l.*, or 66.6 per cent., compared with the same period for 1914–15.

THE ENGINE-ROOM HEROES' MEMORIAL, LIVERPOOL.

HEROISM is not peculiar to any calling or to any social class, but the honours and dignities which are awarded in recognition of it are apt to fall unevenly, some callings and classes getting far more than a proportionate share. Probably no occupation, apart from those of a naval or military character, makes at times a greater demand on nerve and courage than that of a sea-going engineer or mechanic; but the deeds which are done are seldom heard of, and still more seldom publicly acknowledged. Statues decorate our streets and squares and call to mind heroic acts in all parts of the world done by soldiers and sailors, but the quiet performance of duty at imminent risk, but under commercial conditions, never received such recognition until the memorial commemorating noble sacrifice and devotion of the Engine-Room Staff of Engineers, Electricians, Boilermakers and their associated workers, who lose their lives at sea in the fulfilment of their duty, was completed at Liverpool. This memorial, of which a representation is seen on this page, has been erected at the Princes Pier Head, on a prominent and admirable site given by the Corporation, and from a fund raised by world-wide subscriptions.

The memorial is the work of Sir William Goscombe John, R.A., and is symbolic in design and treatment, the motive chosen by the sculptor being the contending nature of the elements Fire and Water.

The design takes the form of a massive rectangular base from which rises an obelisk. On two sides of the base are groups of sculpture representing the different members of a staff; the figures in each group hold the characteristic tools of their office. Inscriptions with appropriate wreaths and emblems occupy the other two sides of the base. At the angles of the upper portion of the base are nude figures representing the elements Earth, Fire, Air and Water. These figures support an ocean-encircled globe behind which rises a flaming Sun.

The obelisk is surmounted by a group of female figures symbolic of the sea, and by a gilded torch suggestive of the triumph of Fire, and commemorative of the services rendered by those who keep the lights burning.

The whole of the monument, including the sculpture, is of grey granite. It is 48 ft. high and surrounded by a raised border of grass about 40 ft. in diameter, with a granite kerb. Granite has been used very little for sculpture in this country, and the memorial is the first important work of its kind in which the whole of the sculpture has been executed in granite and in which the design and treatment have been appropriate to this exceedingly hard and often unsympathetic material. The inscriptions are as follow:—

NORTH PANEL.

In Honour of
All Heroes of the
Marine Engine Room.
This Memorial
Was erected by
International Subscriptions.

SOUTH PANEL.

The brave do not die;
Their deeds live for ever
And call upon us
To emulate their courage
And devotion to duty.

The committee, which had for its president the Hon. Lord Derby, K.G., is to be congratulated on the success of their efforts, and it is to be regretted that, owing to the war, it is considered inexpedient to have an inaugurating ceremony.

The photograph is by Stewart Bale, of Liverpool.

PERSONAL.—The Penn Steel Castings and Machine Company, of Chester, Pa., state that they have amalgamated with the Baldt Steel Company, of New Castle, Del.; the new company will be known as the Penn Marine and Ordnance Castings Company, Inc., and will have executive, general, and sales offices at 132, South 15th-street, Philadelphia, Pa.

IMPERIAL INSTITUTE: THE TRANSFER TO THE COLONIAL OFFICE.—The control of the Imperial Institute will, by the new Act which has recently passed through both Houses of Parliament, rest with the Colonial Office. The change is explained in detail in the current number of the "Bulletin of the Imperial Institute," published this week. By the establishment of an Executive Council a board of management will be created, which, subject to the control of the Colonial Office, will be responsible for the operations of the Institute. The relationship between the Colonial Office and the Institute will thus be analogous to that between the Colonial Office and a Crown Colony. Matters of important policy will have first to receive the sanction of the Colonial Office, but, subject to this, the Executive Council will possess a general executive authority.

ARTILLERY CHRONOSCOPE.

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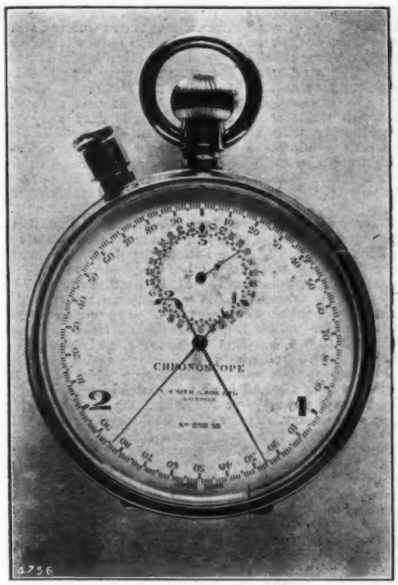


FIG. 1.

FIG. 2.

THE ordinary stop-watch, or chronoscope, has a balance which beats fifths of seconds, and the hand naturally moves five times per second. The reading is obtained in seconds and fifths, and no greater accuracy is possible. When timing the flight of projectiles an interval of one fifth of a second may correspond to 400 ft. of range, which is, of course, a very considerable distance. To enable a nearer approach to accurate measurement to be made, Messrs. S. Smith and Son, Limited, of 6, Grand Hotel Buildings, Trafalgar Square, London, have brought out a chronoscope which has a balance beating hundreths of a second, and consequently the hand moves one hundred times a second, and will measure corresponding intervals of time if properly manipulated. The face and the mechanism of the instrument are shown in the annexed illustrations. It will be seen that there are two dials on the face, a smaller one graduated in 3 seconds intervals up to 3 minutes, and a larger one graduated in hundredths of a second up to 3 seconds. It is thus possible to measure any interval up to 3 minutes 3 seconds without watching the hands. The mechanism is very similar to that of the ordinary stop-watch, but the so-called hair spring is much stiffer (Fig. 2), to give the necessary short period to the balance. The balance is serrated on the edge, so that it can be stopped instantly without lost motion by the levers A and B. When the hand is at zero a peg on the lever A presses against the balance and holds it. On pressing the milled sphere inside the bow the lever B comes forward, and at the same time a peg on its lower side gives the balance an initial rotation to secure its certain start. At the end of the travel of the lever B the balance is free and the watch commences to run. A second pressure on the milled sphere forces a peg on the lever A against the balance and holds it fixed, while a third pressure carries the hand back to zero by aid of a heart cam in the usual way.

The chronoscope is made with a split seconds hand, as in the example illustrated, or with a single hand. The split hand enables two observations to be made in succession without stopping to record them, and in so far is a convenience. But for single observations the solid hand is all that is required.

The value of such an instrument depends on its accuracy and on the skill of the observer. As to the first, the evidence of the National Physical Laboratory is quite satisfactory. To gain its certificate the watch must not have an error of more than $\pm$ 5 seconds in one hour's continuous running, and not more than $\pm$ 2 seconds in the first or last 10 minutes. Further, in 12 runs of 5 seconds, 10 seconds and 15 seconds each, the mean error must not exceed $\frac{1}{10}$ second, and it must decrease as the run is lengthened, until for four runs of 60 seconds each it must not exceed $\frac{1}{100}$ of a second.

The particular object the makers had in view when designing this instrument was the timing of artillery practice. For instance, by taking the period between the flash of a distant gun and the sound of the explosion it is possible to calculate how far away it is from the observer, the speed of sound being known. Or if the period between the firing of a gun and the striking of the target at a known distance is measured, the mean speed of the projectile can be calculated, giving a clue to the condition of the rifling of the gun as regards wear. The setting of fuses can also be checked by the chronoscope, to see if they explode exactly as they should do.

It seems remarkable that the mechanism of a watch can be started or stopped a hundred times in a second with certainty. But this does not represent nearly such a difficult problem as constructing the engine of a motor bicycle to run at 100 strokes per second. This speed is constantly attained, and during the period of a stroke a valve has to be lifted, the mixture drawn in and the valve closed; or the mixture has to be ignited and burnt and a considerable proportion of the products evacuated. In comparison with these operations a stop-watch, even of the extreme accuracy of the one in question, presents a very simple problem, and should give satisfactory results over long periods of time.

THE PHYSICAL SOCIETY OF LONDON.

At the meeting of the Physical Society of London, held on March 24, 1916, at the Imperial College of Science, Professor C. Vernon Boys, F.R.S., President, in the chair, a paper entitled "*The Laws of Variation of Resistance with Voltage at a Rectifying Contact of Two Solid Conductors, with Application to the Electric Wave Detector*," was read by Mr. D. Owen, B.A., B.Sc.

The paper contains an account of an investigation, the primary object of which was to determine the nature of the physical actions occurring at a rectifying contact. Resistance characteristics are given for various contacts, some including a mineral, some in which both elements are metals. It is shown that a *specific characteristic* may be drawn for any given pair of materials. The experimental results are in accordance with the view that the actions are thermo-electric, the main determining factors being the thermo-electric power and the temperature coefficient of electric resistance.

Based on the law of constancy of the voltage coefficient calculations are given showing the best value of the resistance of the telephone in a wireless receiving circuit in which the contact detector is employed. The influence of a polarising voltage is also traced.

The use of the combination of rectifier with a direct-current galvanometer as indicator of the balance-point in an alternating-current bridge is examined, and it is shown that the minimum detectable alternating voltage cannot be reduced much below a millivolt.

Discussion.—Mr. Duddell thought the paper was a very important contribution. He had no definite opinion as to the true explanation of rectifying contacts. In practice very much depended on the exact part of the crystal at which contact was made. With regard to thermo-electric forces, he had examined a large number of crystals in the hope of obtaining contacts which were more stable than those ordinarily employed, and he had concluded that no mineral which did not show thermo-electric effects was of any use as a detector. There might be exceptions in the case of metals, but the rule applied to all sulphides. His experience with regard to the receiving telephone differed somewhat from the author's. In a telephone the resistance and impedance depended on the frequency. In practice it seemed desirable to keep the impedance of the telephone of the same order as the resistance of the detector, and adjust the latter until the desired sensitivity was attained. In receiving strong signals one may employ very tight contacts, in which it appears to be impossible that there should be any air film. A satisfactory rectifying action was still, however, obtained.

Professor G. W. O. Howe thought that it was well to avoid flying off to new hypotheses in order to explain new phenomena, if they could possibly be accounted for on well-known grounds. He was pleased to see that the author had been able to explain rectifying contacts without invoking any mysterious new properties. He was rather surprised to gather from the author's remarks that the thermo-electric theory was generally discredited. His impression had been that the work of Dr. Eccles had established it as the accepted explanation. Had any of the exponents of the electron theory attempted to give a detailed explanation of the observed phenomena on that basis? What was the origin of the "settling down" of contacts mentioned by the author? Was it a mechanical or thermal effect? He would like to hear just in what respect the results of Mr. Owen's work differed from those of Dr. Eccles.

Dr. W. Eccles remarked that he was glad to find such agreement on the absurdity of rushing to special explanations of these phenomena. Certain workers had thought that electrostatic attraction altered the area of contact. Others assumed the opening of trapdoors to let electrons through, the mechanism of the process being considerably more difficult to explain than the original results themselves. Professor Fleming had found that many of the substances used as detectors were photo-electric—i.e., they give off electrons under the action of light—and he assumed that rectifying phenomena were caused by a similar action of the longer electro-magnetic waves. He (Dr. Eccles) had tried to put these points straight by explaining the phenomena in terms of well-known physical properties, such as the resistance coefficient, Peltier effect, &c., and had found it possible to account for all the effects. The theory proved unpopular because it had nothing occult about it. Mr. Owen had dropped the Thomson effect from his treatment. He thought this was not justifiable, as the Thomson effect was a physical fact which must enter into the resulting practice. Leaving it out of consideration simplified the treatment, but lost the explanation of several of the erratic properties of detectors. For instance, the theoretical resistance characteristic curves obtained by Mr. Owen were parabolic. It was obvious, however, that the experimental curves were of the fourth degree. The Thomson effect must be introduced to explain the way the curve bent off at the extremities. One important result of the author's was that for the same materials the value of R_m/R_0 was constant for any contact, light or heavy. This appeared to him to be due to the fact that increasing the area of contact by increasing the pressure was equivalent to putting two or more similar contacts in parallel.

Mr. A. F. Hallimond (communicated): I should like to congratulate the author on his reduction of the curves for each contact-pair to a specific resistance characteristic. If it is found that the same process can be employed in all cases, a very useful and simple means of comparison will be established. The result seems the more remarkable in being based upon the resistance curves, and I should like to ask whether the relation throws any light on the conditions obtaining at the contact when the pressure is varied. With reference to the heating of the contact, I believe that Professor Pierce observed that at 80 cycles no lag occurred, such as might be due to heating. The author's arrangement by which the current may pass from 0.003 second would seem to be even more sensitive. Was any variation observed in the resistance with the time of passage of the current? With regard to the thermal effects, may I suggest the investigation of pyrite, a mineral in which adjoining areas may exhibit widely different thermal E.M.F.?

The author (in reply) said he was glad to learn that it was Mr. Duddell's uniform experience that high thermo-electric power and sensitiveness of a contact detector go together. In regard to the relation of impedance of telephone to the resistance of the contact he was quite prepared to find that the conclusions deduced from the simple treatment employed in the paper required modification to conform to the actual conditions of practice. In reply to Professor Howe's inquiry as to the cause of the "settling down," this was not due to thermal action; the small testing voltage was applied only at intervals, and was not itself the cause of the change described. The effect appeared to be of the nature of an adjustment of the molecules bounding the contact when their setting was changed; it was probably allied to the slow changes met with in the study of elastic strains. He did not go so far as to say that the thermo-electric theory had become generally discredited, but rather that it stood in need of confirmation. He would endeavour briefly to point out in what relation his own work appeared to stand to that of Dr. Eccles; this reply would cover some points of difference which Dr. Eccles had commented upon. Dr. Eccles employed coefficients representing the Peltier effect, the Thomson effect, and the temperature coefficient of resistance. The author found that the existence of softening and consequent increase of area of contact due to rise of temperature became very important at the higher voltages. This effect was compli-

cated and thus not amenable to mathematical treatment; the course adopted in the present paper was, therefore, to restrict the application of the formulæ within small limits of voltage—say, a few tenths of a volt. Apart from this, the chief point of difference was in the emphasis laid on the relative value of the coefficients. The author found that the experimental results in the case of all the mineral and metallic contacts tested might be explained without invoking the Thomson effect; the conclusion was, therefore, drawn that this term was of small importance in comparison with the Peltier effect, at all events at low voltages. It thus fortunately became possible to simplify the theory appreciably. Again, in the author's view, not only did resistance admit of more precise measurement, but the statement of results in the form of resistance characteristics brought out the essential features of the behaviour of these contacts more clearly than if current characteristics were employed. In reply to Mr. Hallimond, the determination of resistance of contact as a function of pressure was not specially considered in the paper. The tests there recorded tended, however, to show that pressure only entered in so far as it altered the area of contact. In regard to the question of time-lag, this was the subject of experiments now in progress. In reference to pyrite, the author fully granted that heterogeneity might and did exist in this and other cases; for further instance, in the high and low-resistance specimens of carborundum referred to in the paper, both possessing high thermo-electric power, but of opposite signs in the two cases.

A paper entitled "*The Electrical Capacity of Gold-Leaf Electroscopes*" was read by Dr. T. Barratt, A.R.C.S. A gold-leaf electroscope is frequently used to compare exceedingly small ionisation currents. For this purpose it is much more sensitive than a quadrant electrometer. If the capacity of the electroscope is known, then the absolute value in amperes of the ionisation current can be deduced. A method is described for measuring the capacity of a gold-leaf electroscope, the method depending on sharing the charge of a parallel plate air-condenser of measurable capacity as many times as necessary, and deducing the capacity of the electroscope from the observed drop of potential. The method gives consistent results when the experimental conditions are widely varied. The amount of deflection of the leaf appears to have little influence on the result.

On account of the lateness of the hour, the paper was not opened for discussion. Several Fellows communicated remarks to the author, and these, together with his reply, will appear in the "Proceedings."

SOME EFFECTS OF THE BULKHEAD COMMITTEE'S REPORTS IN PRACTICE.*

By A. T. WALL, A.R.C.Sc., Associate Member.

(*Concluded from page* 440.)

PART III.—THEIR INFLUENCE ON DESIGN WORK.

IT has already been noted that the introduction of the Bulkhead Rules adds considerably to the work of designers, and they must be carefully considered in working up the principal particulars of a ship. It is now necessary to examine every ship coming under notice with a view to determining what alterations would be necessary to make it conform to the Bulkhead Rules. It will invariably be found that some modification is necessary from the arrangement that was common before the introduction of the Subdivision Rules. To arrive at a satisfactory arrangement, it is generally necessary to take out several curves of permissible length. Whether the required changes are large or small, the first permissible length curve deduced is not usually suitable, and perhaps two or more additional curves would have to be obtained before the final combination of draught and depth is arrived at.

In practically all cases one or more compartments will be much longer than the permissible length. After additional bulkheads have been put in, it will be found that one or more compartments are just over or just under the permissible length. This is illustrated in Fig. 12. The vessel cannot float at the draught corresponding to the lower set of curves shown, unless an additional bulkhead is provided forward and aft. In all probability this would not be done, but instead the draught would be slightly decreased. With the upper set of curves the draught should be increased in order to obtain the maximum dead weight under the rules. In the ordinary way, this decrease or increase of draught would have to be guessed at, and a new permissible length curve lifted. If this curve did not fulfil the conditions, a second curve would have to be deduced, and so on until all or nearly all the compartments were just on the limiting permissible length. All these operations take up valuable time, and it would be advantageous if some general relation could be established between the changes in floodable lengths, at any position in the ship, with changes in freeboard ratio, block coefficient, sheer ratio, and permeability.

Variation of Floodable Length with Freeboard Ratio.—With this object in view a series of curves was set out (see Fig. 13). These were obtained as follows. At first only standard-form ships were considered, and four vessels were taken having block coefficients of 0.52, 0.60, 0.72, and 0.83, when the freeboard ratio was 0.5. The floodable length curves for these four ships were then lifted from the series of cross-curves given in vol. ii. of the First Report of the Bulkhead Committee, Plates II.–XXV. These floodable lengths were taken for four values of freeboard ratio (0.1, 0.3, 0.5, and 0.7); that is, from about the lowest to the highest dealt with in the cross-curves mentioned. With each of these freeboard ratios three different sheer ratios were taken (the two shown and zero sheer). For each station in the ship, curves of floodable length were now set out on a base of freeboard ratio for the different sheer ratios and block coefficients taken. Fig. 13 shows a typical set. Four spots on the floodable length curve were obtained in this way, and since the floodable length is practically zero when the freeboard ratio is nil, a fifth spot was available for each curve. At the other freeboard ratios taken the correct block coefficient to use was deduced from the curves of mean water plane coefficients given in Plate XXVI., in vol. ii. of the First Report of the Committee. This procedure ensured that the block coefficient varied with freeboard ratio in exactly the same way as for the standard ships chosen by the Committee.

It will be noticed that these curves have considerable curvature at their upper ends, but are more or less straight in the lower portions. It is clear that if they could be taken as straight over the ordinary practicable range of freeboard ratios, the change of floodable length with that ratio would be considerably simplified.

In view of what has been said in Part II., page 439 *ante*, under "Freeboard and Sheer in New Ships," attention was only paid to the change in floodable length with freeboard ratio between the values 0.20 and 0.65. It was found that the errors were rather large if a linear variation was assumed over the whole of this range, and in consequence two different ranges were used, from 0.2 to 0.4 and from 0.35 to 0.65.

The method by which the straight lines for mean floodable length were obtained is discussed in detail in Appendix I., but it may be mentioned here that they were set out for the floodable-length curves given by a sheer half way between the two highest values used in obtaining the curves shown in Fig. 13; that is, a sheer ratio of 0.352 forward and 0.176 aft, expressed in terms of the draught at 0.5 freeboard ratio. The change of floodable length with freeboard ratio is different at the different stations in the ship, and it also varies with block coefficient and permeability, as will be noticed later. There is, in addition, a very slightly different rate of change in the floodable length for different sheer ratios, but for all working values of sheer ratio it is particularly small. It would be safe to assume that the rate of variation is unaltered for ships having sheer ratios lying between the standard sheer ratio and that 75 per cent. above it, the standard mean sheer in inches being taken as one-tenth of the length of the ship in feet, plus 10, and for convenience the sheer forward is taken as twice that aft.

The greatest error will occur at the extreme limits of the ranges of freeboard ratios taken. This fact was used in setting out the mean line, which was drawn in to give equal percentage errors in draught at each end of the freeboard ratio range. The method of procedure is fully described in Appendix I. Finally, however, this line was not used. In order to keep the percentage change in floodable length independent of permeability (as explained in Appendix II.) a different mean line was taken. The error in the draughts so deduced will very rarely exceed 1 per cent. when taken over a range in freeboard ratio of 0.1 when working within the limits occurring in practice.*

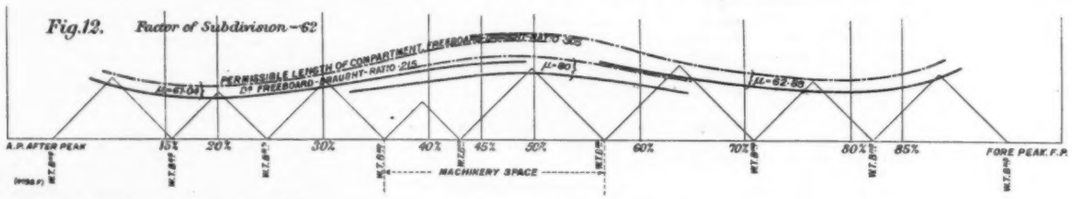
Up to now no consideration has been given to ships with forms varying from the standard. Several existing ships, therefore, were taken whose forms differed widely from those of the standard forms, and curves of floodable lengths were obtained by the methods given in the Committee's reports. These curves were set out in the same manner as that described for the standard form, and the same procedure followed. It was seen that, although the actual floodable lengths may vary very considerably with change of form, it was still fairly accurate to assume that the change in floodable length with freeboard ratio was linear over the range of freeboard ratios taken. The errors involved in so doing are only slightly greater than those in the standard-form ships.

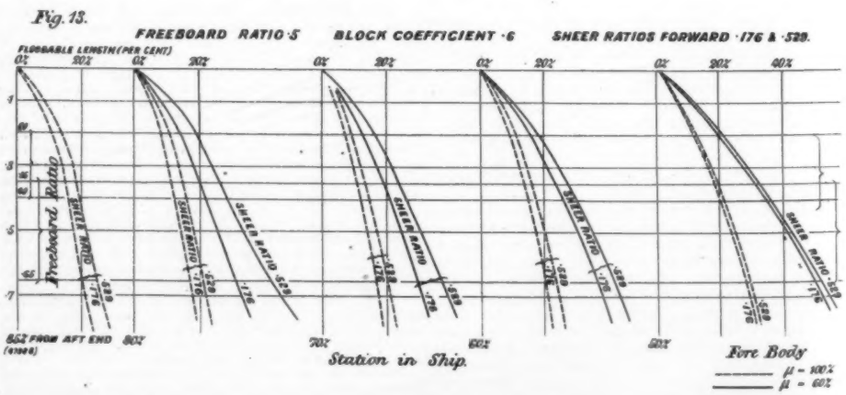
Curves of percentage change in floodable length with freeboard ratio on a base of position in ship are set out in Figs. 14 and 15. The first diagram gives the values over the range 0.35 to 0.65 of freeboard ratio. The necessary interpolation for block coefficient, which is based on the draught at 0.5 freeboard ratio, can be done directly without any complication. The second diagram gives similar values for the range of freeboard ratios from 0.2 to 0.4, but the block coefficient is based on the draught at 0.3 freeboard ratio.

Percentage Curves.—In treating a ship under the Rules by this method it could probably be decided by inspection if any large increase in depth to the bulkhead deck is necessary. If the draught desired, or that which it was expected to attain, gave a freeboard ratio within the range 0.35 to 0.65, the curve of permissible length would be lifted at 0.5 freeboard ratio. This curve would be accurate in every detail, and by using the percentage curves in Fig. 14 a number of approximate curves of permissible lengths could be immediately obtained for any other freeboard ratios. A similar procedure would be adopted for freeboard ratios between 0.2 and 0.4.

Curves deduced in this way are shown in Fig. 16, together with the accurate curves as lifted from the Rules. The curves are explained in the figure, and it will be seen that the differences are by no means large, in this case never giving an error of more than 1 per cent. in draught, and not enough to render necessary any drastic alterations to the ship. In any case, a final curve must be submitted to the Board of Trade. Such errors in draught are not without precedent, as it often happened when working under the Load Line Tables that the load draught as deduced by the shipbuilders or shipowners was somewhat different from that finally granted by the Board of Trade. Further, the draught aimed at in the calculations, in order to guarantee a dead weight, would be fixed so as to include a certain margin for contingencies. This would probably cause the actual draught to be less than the one used in the calculations.

Should it be preferred to lift an accurate curve of permissible length at the likely freeboard ratio directly, it would probably have a similar relation to the inter-





* Paper read at the Institution of Naval Architects, April 13, 1916.

* See Appendix III.

of the ordinate of the "permissible" curve. At the centre of each of the compartments in the ship the percentage change in floodable (or permissible) length for a change of 0.1 in freeboard ratio (at 0.5 or 0.3 freeboard ratio) can be lifted from one of the Figs. 14 and 15. A formula given in these figures enables the percentage change at any other freeboard ratio to be deduced. The necessary change in freeboard ratio can therefore be easily obtained.

The actual change of freeboard ratio that can be given to the ship will be the smallest of the values so obtained if the compartments are under the permissible length, and the largest if the compartments are over the permissible length. It would not generally be necessary to treat every compartment in the ship in this way. If the compartments are under the permissible length, it will usually happen that some of them are too far under to be adversely affected by the small change made in freeboard ratio in bringing the remaining compartments to their limiting values. A similar thing is true for the opposite reason when the compartments are over the permissible length.

There are other uses to which the "percentage curves" shown in Figs. 14 and 15 can be put, but they need not be mentioned in detail here, as they will be apparent to those who have had occasion to use the Bulkhead Rules.

Another Method.—Since it has been shown that over a limited range of freeboard the variation of floodable length with freeboard ratio may be taken as linear, it follows that there is another method open to use by which very close approximations may be made to floodable length curves at a freeboard ratio differing from that for which the curve has been lifted. It would only be necessary, having settled on the approximate freeboard ratio at which the vessel is likely to run, to lift two floodable length curves at two freeboard ratios, one lower and the other higher, and to assume that the variation of floodable length with freeboard ratio between these two values is linear. This would not be especially complicated when dealing with standard-form ships, although it has been shown by actual test that it is much quicker to lift only one floodable-length curve for the standard form, and then use the "percentage curves" already described for other freeboard ratios. This is due to the fact that different coefficients and ratios have to be obtained for each freeboard ratio at which a floodable length is lifted, apart from the actual lifting of the floodable-length ordinates from Plates II. to XXV. in the Rules." With ship forms the process of lifting a floodable-length curve takes still longer, and the advantage derived from the use of the percentage curves is more marked.

Approximate Curves of Floodable Length with Simplified Application.—It appears that something could be done to simplify the application of the rules for subdivision, if it were agreed that some accuracy could be sacrificed as compared with that of the system already in operation. In view of the fact that the mathematical accuracy in setting out the curves of floodable length has little significance in practice, the following method is put forward, which may be considered accurate enough for all practical purposes. Two fundamental assumptions are made in dealing with standard-form ships. It is at first assumed that the actual range of freeboard ratio likely to occur in ships of the future is limited, say, from .25 to .65, or from .20 to .65, and that over this range the variation of floodable length with freeboard ratio might be assumed as linear. From what has already been said it will be seen that errors are introduced by doing this, although these would not be excessively high. The second assumption to be made is that at a given freeboard ratio in a given ship, variation of floodable length with sheer ratio is also linear. The error introduced by this assumption is quite small over the practical range of sheer ratios. This can be seen by an inspection of the sheer ratio lines given on Plates II. to XXV. of vol. i. of the First Report of the Bulkhead Committee. It is clear from this that approximately equal increments of floodable length are given by equal sheer increments. This was also tested by actually plotting curves of floodable length on a base of sheer ratio at different freeboard ratios and blocks. If these assumptions are allowed, two out of the five variables which determine floodable length are eliminated. Contour curves of floodable length on a base of block coefficient for varying permeabilities at any station in the ship can now be plotted for standard freeboard and sheer ratios, and would be as shown in Fig. 17, page 488.

It has been shown that the variation of floodable length with freeboard ratio varies with the block coefficient. In order, therefore, to obtain the floodable length at some other freeboard ratio than that for which the curves in Fig. 17 have been plotted, a curve of percentage variation for a change of 0.1 in freeboard ratio could be plotted below the base line as shown. The correction for varying sheer would be simply expressed as an addition to or subtraction from the floodable length for, say, an increase or decrease of 0.05 in the sheer ratio.

If these admitted approximations should be considered to give sufficient accuracy for practical purposes, it becomes a very simple matter to lift the floodable length curve for the standard-form ship. The floodable length would be lifted at the freeboard and sheer ratios for which the curves are plotted, and the additions or subtractions for other sheer and freeboard ratios made as necessary in one operation. The total to add or subtract would, of course, vary with position in the ship.

The error introduced by using this approximate method can be looked upon as the same thing that would occur by using the accurate curves with a factor of subdivision different from that given by the Committee. This factor must be, from its nature, somewhat arbitrary, especially as it depends on the criterion of service, which, in turn, depends on an assumed permeability. Viewed in this light the approximations do not appear to be as serious as otherwise.

If these more or less empirical principles were agreed to, design work would be enormously simplified, since the floodable lengths could be more easily lifted from the curves, and the effect on floodable length by alteration of any of the variables—whether it be block coefficient, permeability, freeboard ratio, or sheer ratio—could be immediately set out. In addition, the 24 sets of curves given in Plates II. to XXV. of the First Report would be replaced by 12 of the type shown in Fig. 17. These latter curves would be much easier to use, and the correction for permeability would be obviated. The curves of area and inertia coefficients and centre of flotation of the mean water-plane given in Plate XXVI. would be replaced by one diagram (Fig. 18), giving these values directly on a base of block coefficient. The 12 curves in Plate XXVII., giving the sectional area coefficients for the standard form, would be replaced by a set of curves in one diagram (Fig. 19), giving sectional area coefficients on a base of position in ship for different block coefficients.

For ships varying from the standard the matter is more complicated, and, if any simple scheme is to be devised, it seems necessary to introduce further approximations. Lack of time has prevented the writer from going more fully into this matter, but enough has been done to show that something is possible in this direction.

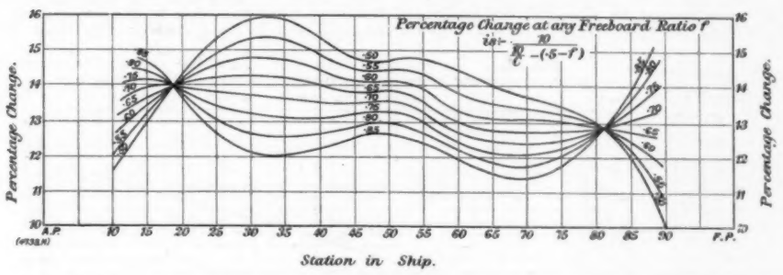
The first simplification would be only to consider variations from the standard at the standard freeboard and sheer ratios for which the curves, as those shown in Fig. 17, have been set out for the standard form. This could be done by means of Table III., given on page 32 of vol. i. of the Committee's First Report.

Variations of freeboard and sheer ratios from the standards adopted would be dealt with in exactly the same way as for the standard-form ships, and the facility with which these curves could be used would be the same.

All the curves, such as those described in Figs. 17, 18, and 19, could quite well be expressed in tabular form, and it is considered by many that in such a form they would be easier to use. It was a suggestion emanating from responsible people in the shipbuilding world that

Fig. 14. PERCENTAGE CURVES. "C" VALUES.

CURVES OF PERCENTAGE CHANGE IN FLOODABLE LENGTH AT ·5 FREEBOARD RATIO FOR A CHANGE OF ·1 FREEBOARD RATIO; FOR ALL PERMEABILITIES AND BLOCK COEFFICIENTS AS SHOWN. RANGE OF FREEBOARD RATIO=·25 TO ·65.



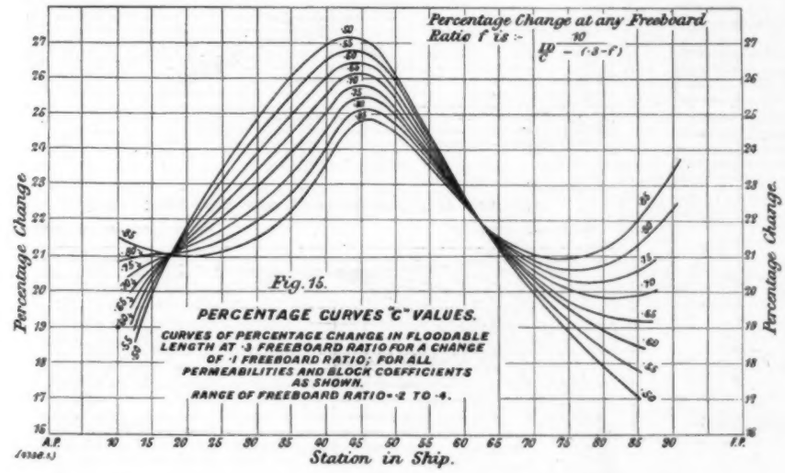


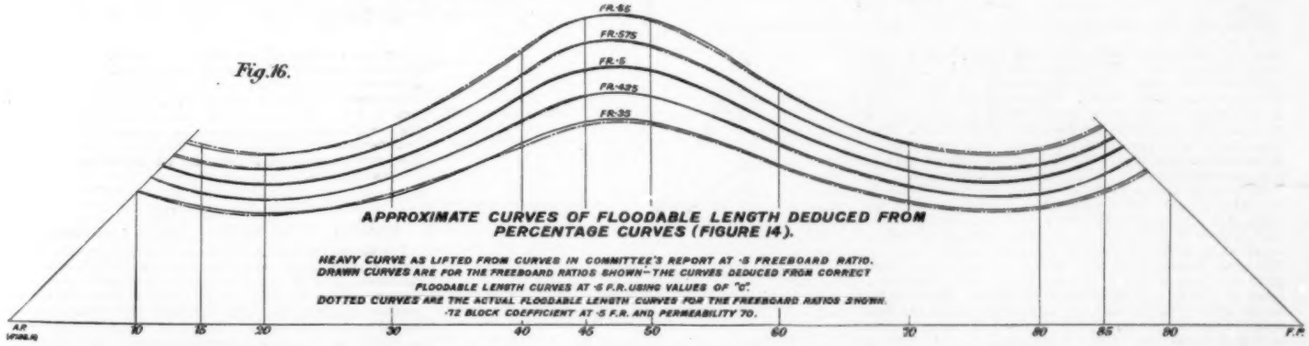
Fig. 15.

PERCENTAGE CURVES "C" VALUES.

CURVES OF PERCENTAGE CHANGE IN FLOODABLE LENGTH AT ·3 FREEBOARD RATIO FOR A CHANGE OF ·1 FREEBOARD RATIO; FOR ALL PERMEABILITIES AND BLOCK COEFFICIENTS AS SHOWN.

RANGE OF FREEBOARD RATIO=·2 TO ·4.

Fig. 16.



APPROXIMATE CURVES OF FLOODABLE LENGTH DEDUCED FROM PERCENTAGE CURVES (FIGURE 14).

HEAVY CURVE AS LIFTED FROM CURVES IN COMMITTEE'S REPORT AT ·5 FREEBOARD RATIO.
DRAWN CURVES ARE FOR THE FREEBOARD RATIOS SHOWN—THE CURVES DEDUCED FROM CORRECT FLOODABLE LENGTH CURVES AT ·5 F.R. USING VALUES OF "c".
DOTTED CURVES ARE THE ACTUAL FLOODABLE LENGTH CURVES FOR THE FREEBOARD RATIOS SHOWN.
·72 BLOCK COEFFICIENT AT ·5 F.R. AND PERMEABILITY 70.

such tables would be advantageous, which first induced the writer to consider if such a course was at all possible. This must be used as the excuse for putting this method forward, which is admittedly approximate. It is hoped, however, that it may serve as a means of stimulating discussion on the matter, as it appears to be one which has seriously exercised the minds of many people concerned with the application of the Bulkhead Rules.

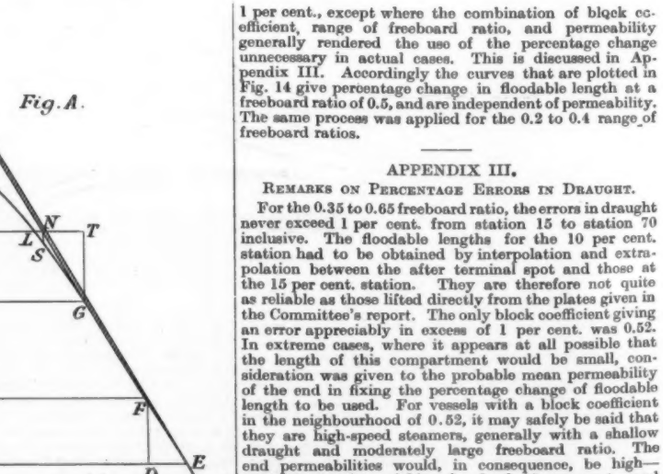
In conclusion, the writer wishes to express his thanks to Mr. G. J. Carter, managing director of Messrs. Cammell, Laird and Co., Limited, for permission to publish the results. His thanks are also due to numerous friends for assistance in particular parts, and especially to Mr. J. C. M. Wilson for considerable help with the large amount of detail work connected with the paper.

APPENDIX I.

METHOD OF OBTAINING PERCENTAGE CHANGE IN FLOODABLE LENGTH.

As already described, curves of floodable length were set out on a base of freeboard ratio (see Fig. 5, page 400 *ante*), four such sets being drawn for block coefficients of 0.52, 0.60, 0.72, and 0.83. The scales used were $\frac{1}{4}$ in. = 0.01 freeboard ratio, and $\frac{1}{4}$ in. = 1 per cent. of total length of ship for floodable length. By means of these curves it was shown that the errors involved by assuming a straight line variation for floodable length with freeboard ratio were practically the same over the range of sheer ratios mentioned in the body of the paper; that is, from standard sheer to about 75 per cent. above it.

Suppose in Fig. A that Q G E is a curve of floodable length on a base of freeboard ratio, and assume that the point O is taken, through which the mean line for floodable length is drawn, it is necessary to find the error involved by assuming that the floodable length lies along this line. Draw the horizontal line A G at a freeboard ratio of f, and above it the line H L T at a freeboard ratio of $f - 0.1$. The percentage change of floodable length is now to be assumed as that given by the line G O. This will cut the line H T above the actual curve Q G E at a point N. Draw N S parallel to O A, cutting the curve at "S," then N S is the error in freeboard given by using a straight line variation of floodable length with freeboard. Denote this by e. The actual freeboard ratio arrived at by going along the straight line O G is $f - 0.1 - e_1$. Suppose now that the actual floodable length has been lifted at the freeboard ratio f, the draught deduced by using the straight line variation will be $\frac{D}{1 + f - 0.1 - e}$, while the correct draught should be $\frac{D}{1 + f - 0.1}$. The error in draught is the difference of the two, and can be expressed as a percentage of the correct draught. A similar reasoning applies at the lower part of the curve, where the error can be expressed as a percentage in the same way. If the range of freeboard be now settled over which it is desired to assume the linear variation, the percentage error in draught can be estimated over the range in going from freeboard ratios 0.1 inside each end to the limiting values. To obtain a position of the point O which would give equal errors in draught, various points were taken along the base line B O, and the actual percentage errors in draught obtained at each end of the range. Curves were then plotted having these percentage errors as ordinates, and the positions chosen for the points as abscissæ. The intersection of these curves gives the point to be taken for equal errors. For this purpose, to ensure accuracy the curves of floodable length for a sheer of 0.352 forward and 0.176 aft were all set out on a large scale; $\frac{1}{2}$ in. = 0.1 freeboard in ratio and $\frac{1}{2}$ = 1 per cent. for floodable length.



APPENDIX II.

EFFECT OF PERMEABILITY ON PERCENTAGE CHANGE IN FLOODABLE LENGTH.

The percentage change in floodable length, as represented by a linear variation, will vary with the floodable length, and the values must accordingly be taken at some agreed freeboard ratio. The freeboard ratio of 0.5 was taken for the 0.35 to 0.65 range, and, referring again to Fig. A, below, it will be seen that the percentage change of floodable length going along the line G O for a change in freeboard ratio of 0.1 is D F; that is, 0.1 divided by B O. These values were now plotted for the different freeboard ranges and permeabilities on a base of position in ship, separate curves being drawn for the different block coefficients. It was found that these gave very awkward curves, which sometimes changed very rapidly from one station to the next, and crossed and recrossed for the different block coefficients. As such, they would prove very complicated to use. A method was therefore sought whereby they could be plotted in a more amenable form. From the curves that were set out for errors in draught it was found in the majority of cases that the percentage change in floodable length could vary quite appreciably from the values giving minimum error without introducing an error in the draught of more than 1 per cent. The limiting values of these percentage changes were therefore obtained and plotted for the different block coefficients on a base of position in ship. This was at first done separately for each of the permeability values and each of the freeboard ranges. So long as the curve of percentage change in floodable length lies between these limiting spots, the error in draught will not be greater than 1 per cent. This enabled the tortuous curves already referred to to be replaced by more or less fair curves. It was then found that these ranges of percentage change in floodable length generally overlapped for the two permeabilities, and it was thought possible to draw in curves of percentage variation which would be independent of permeability. This caused the percentage error in draught to exceed the minimum, but it never made it appreciably exceed 1 per cent., except where the combination of block coefficient, range of freeboard ratio, and permeability generally rendered the use of the percentage change unnecessary in actual cases. This is discussed in Appendix III. Accordingly the curves that are plotted in Fig. 14 give percentage change in floodable length at a freeboard ratio of 0.5, and are independent of permeability. The same process was applied for the 0.2 to 0.4 range of freeboard ratios.

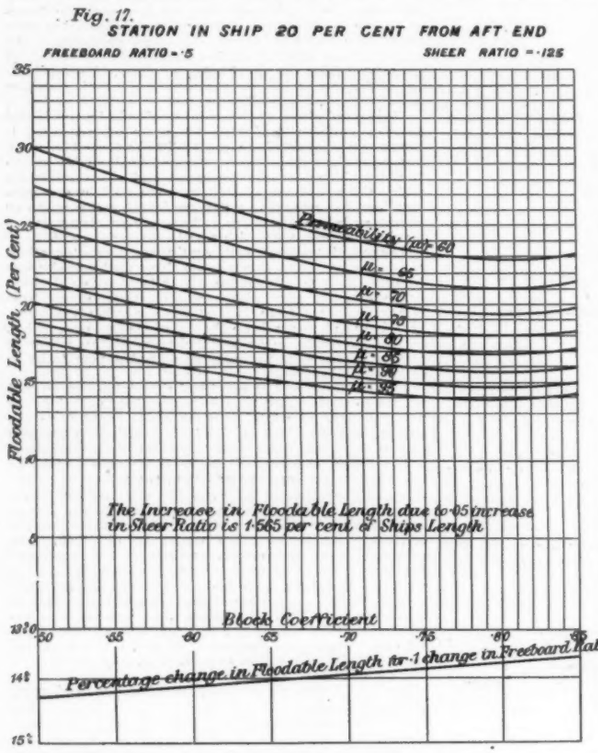


Fig. 17.
STATION IN SHIP 20 PER CENT FROM AFT END
FREEBOARD RATIO = ·5
SHEER RATIO = ·125
Floodable Length (Per Cent)
Permeability for 60
The Increase in Floodable Length due to ·05 increase in Sheer Ratio is 1·565 per cent. of Ships Length
Block Coefficient
Percentage change in Floodable Length for ·1 change in Freeboard Ratio

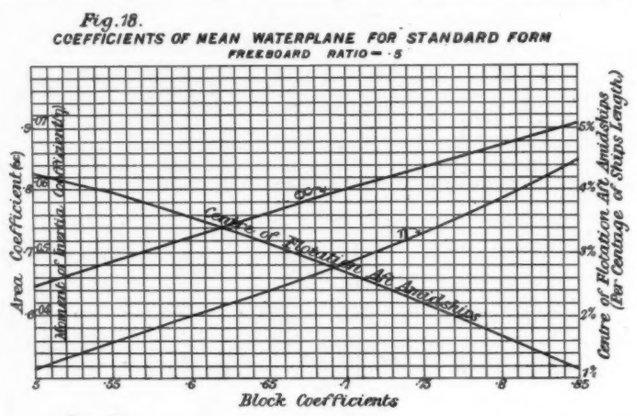


Fig. 18.
COEFFICIENTS OF MEAN WATERPLANE FOR STANDARD FORM
FREEBOARD RATIO = ·5
Area Coefficient (α)
Moment of Inertia Coefficient (β)
Centre of Flotation Aft Amidships (Per Centage of Ships Length)
Block Coefficients

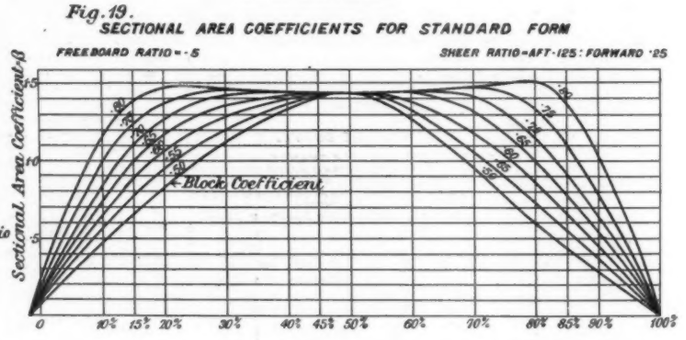


Fig. 19.
SECTIONAL AREA COEFFICIENTS FOR STANDARD FORM
FREEBOARD RATIO = ·5
SHEER RATIO = AFT ·125 : FORWARD ·25
Sectional Area Coefficient-β
Block Coefficient

APPENDIX III.

REMARKS ON PERCENTAGE ERRORS IN DRAUGHT.

For the 0.35 to 0.65 freeboard ratio, the errors in draught never exceed 1 per cent. from station 15 to station 70 inclusive. The floodable lengths for the 10 per cent. station had to be obtained by interpolation and extrapolation between the after terminal spot and those at the 15 per cent. station. They are therefore not quite as reliable as those lifted directly from the plates given in the Committee's report. The only block coefficient giving an error appreciably in excess of 1 per cent. was 0.52. In extreme cases, where it appears at all possible that the length of this compartment would be small, consideration was given to the probable mean permeability of the end in fixing the percentage change of floodable length to be used. For vessels with a block coefficient in the neighbourhood of 0.52, it may safely be said that they are high-speed steamers, generally with a shallow draught and moderately large freeboard ratio. The end permeabilities would, in consequence, be high—probably in the neighbourhood of 90 per cent., and above. The curve was therefore drawn in to give the least error at 100 per cent. permeability. The same applies at the 80, 85, and 90 per cent. stations, where the curve for the different block coefficients, however they were drawn in, gave errors sometimes appreciably greater than 1 per cent. for one or both of the permeabilities. With a vessel having a large block coefficient it may safely be taken that she has a large cargo capacity, and in consequence the end permeabilities would be low, probably not exceeding 63 per cent. The

curves, therefore, at the large block coefficients were drawn in to give small errors on the 60 per cent. permeability, and for the reason stated for the after end, to give small errors at the small block coefficients on the 100 per cent. permeability.

On the 0.2 to 0.4 freeboard ratio range the errors are, as might be expected, somewhat greater than 1 per cent. in quite a few instances. It was, however, thought, after consideration of the various combinations of block coefficient, permeability, and freeboard ratios that might occur, that the curves could be drawn in so that the errors in actual cases would never exceed 1 per cent. by an appreciable amount. Low freeboard ratios will only occur in very short and moderate length vessels, and then only if they are principally used for cargo. It is hardly likely that they would carry any passengers below the bulkhead deck, or at the most a small number, and the end permeabilities would, therefore, be quite small. In drawing in the percentage curves, therefore, preference was given to small errors on the 60 per cent. permeability as being that most likely to be used. The errors for the 100 per cent. permeability as a result often exceed 1 per cent., but in very few cases do they exceed that value for the 60 per cent. permeability. It is doubtful if it will ever be necessary to use the 0.52 block coefficient for this range of freeboard ratio at all; the range of block coefficients occurring in practice will probably be from 0.7 to 0.8.

COLONIAL AND FOREIGN ENGINEERING PROJECTS.

WE give below some data on several colonial and foreign engineering projects, taken from the *Board of Trade Journal*. Further information on these projects can be obtained from the Commercial Intelligence Branch, Board of Trade, 73, Basinghall Street, London, E.C.

Australia.—The Sydney office of H.M. Commissioner for Australia has forwarded a copy of a specification and tender form, &c., in connection with a call for tenders by the Metropolitan Board of Water Supply and Sewerage at Sydney for the supply, delivery, and erection at Ryde Pumping Station of main and branch steam-piping, stop-valves, bolts, jointing material, hangers, brackets, drainage pockets, steam-taps, &c. (Contract No. 1049.) Tenders will be received at the offices of the Metropolitan Board of Water Supply and Sewerage, 341, Pitt-street, Sydney, N.S.W., up to 2 p.m. on July 3. Each tender must be accompanied by a cash deposit of 10*l.*, or a marked cheque for that amount.

Colombia.—The *Diario* contains a Resolution of the Colombian Ministry of Public Works approving the plans for the construction of the section of the Pacific Railway between Bugalagrande and Castago.

Brazil.—The *Diario Official*, Rio de Janeiro, publishes a Decree (No. 11,999) authorising the operation of the Companhia Pecuaria e Frigorifica do Brazil in the Republic, with headquarters at Rio de Janeiro. The company will have a capital of 5,000,000 milreis (about 250,000*l.* at present exchange), and its main object will be the erection and working of slaughter-houses, cold stores, &c., in connection with the export of Brazilian produce. A site for the erection of a slaughter-house, &c., in the State of Rio de Janeiro has already been obtained.

Argentina.—The *Boletin Oficial*, Buenos Aires, publishes a Decree approving plans for irrigation works to be carried out in Olta, Province of La Rioja, at an estimated cost of 125,657 pesos currency (about 11,000*l.*). The *Boletin* also contains a Decree approving the project for the supply of water and the carrying out of sanitary works at a hospital at Bell Ville, in the Province of Córdoba, at an estimated cost of 191,770 pesos currency (about 16,800*l.*). A public call for tenders for the execution of the works will be made by the Comisión Asesora de Asilos y Hospitales Regionales, Belgrano 909, Buenos Aires.

COAL AND RAILWAYS IN THE BALKANS.—The Hungarian Commercial Museum has received a report from Jaffa, according to which the industrial and commercial position remains unaltered, in spite of the opening of the direct railway connection, Berlin–Budapest–Sofia–Constantinople. No consignments of goods have arrived. Firms intending to do business in those regions are recommended to prepare the way by sending out catalogues and other trade literature. A good market for agricultural machinery is anticipated in Palestine and other parts of the near Orient. A report from Constantinople to the same museum states that on account of the coal famine in Constantinople coal can now be imported into Turkey free of duty, as long as the war lasts. Constantinople has to rely upon rail-borne coal, and at present some 30 wagons of coal arrive every day from Germany. The Bulgarian Government has decided that the Ferre–Okdsilar railway, which formerly was in French possession, is to pass under the Bulgarian State management. This means, as the Svilengrad–Kuheli, Burgas–Dedeagatch line of 186 kiloms. length was taken over by the State last October, that all the Bulgarian railways are now being worked by the State. The two lines Ferre–Oksidar (158 kiloms.) and the Dedeagatch line (9.3 kiloms.) form a section of the so-called connection line Salonica–Constantinople, which originally was built by the Turks for strategical purposes. With the two new lines the extended Bulgarian railway system has an aggregate length of 2560 kiloms., normal gauge, besides a normal-gauge industrial railway from the Sindel station, on the Rustchuk–Varna line, to the Tsali–Meschle station, in the interests of the timber of the district.

CATALOGUES.

Safety Appliances for Grinding-Wheels.—The Webster and Perks Tool Company, of Springfield, Ohio, U.S.A., have sent us a catalogue of wheel-guards for grinding-machines, and special safety-flanges for holding grinding-wheels.

Electric Lamps and Flexible Cords.—We have received from the General Electric Company, Limited, of 67, Queen Victoria-street, E.C., a list giving prices and particulars of Robertson carbon-filament electric lamps. The list includes standard lamps for high and low voltages, traction lamps, candle lamps, tubular lamps, battery lamps, and special lamps for electric signs. In another list, also to hand from this firm, particulars are given of flexible cords for electric lighting and power purposes, lift cables, motor-car flexibles, &c.

Weighing-Machines and Weighbridges.—Messrs. Samuel Denison and Son, Limited, of Hunslet Foundry, Leeds, have sent us a copy of their latest catalogue of weigh-bridges and weighing-machines. The catalogue includes weighbridges with and without recording apparatus for railway and road wagons, pit-bank weighing-machines, platform weighing-machines, scales and weights, spring balances, weighing-machines and overload detectors for cranes, locomotive-wheel balancing machines, and other apparatus for special purposes. The catalogue is very fully illustrated and prices are stated in most cases.

Electric Motors and Starting Rheostats.—A descriptive list to hand from the British Thomson-Houston Company, Limited, of Rugby, gives full particulars of small motors ranging from $\frac{1}{20}$ to $\frac{1}{4}$ horse-power, for use on continuous-current or single-phase circuits at 110 and 220 volts. We have also received from this firm a price-list of a new line of totally-enclosed starters for continuous-current motors up to 40 horse-power, and for pressures up to 550 volts. These starters are each enclosed in a cast-iron case having a glass window, through which the resistance contacts are visible, and the rheostat arm is moved by a crank-handle outside the case. Each starter is fitted with no-voltage and overload releases, and the resistance elements are composed of a special non-corrodible wire wound on fire-proof tubes and fitted with porcelain insulators at each end. The resistance units are coated with a special cement, which keeps the wires in place in the event of a burn-out, so that there is no possibility of detached wires coming into contact with the frame or other parts.

Diesel Engines.—Messrs. Mirrlees, Bickerton and Day, Limited, of Hazel Grove, near Stockport, have sent us a pamphlet relating to their new crosshead type of Diesel engines. The construction of these engines is similar to that of an ordinary marine steam-engine; that is to say, a piston, piston-rod, crosshead, and slipper-guide are employed, instead of the more usual trunk piston. In this design, it is claimed, piston troubles are reduced to a minimum, smoother running is secured, troubles with the connecting-rod top-end bearings are avoided, and wear of cylinders is reduced. There are also several advantages in connection with lubrication; but on the other hand, the cost of construction is necessarily augmented and the height of the engine is increased. The latter feature, however, does not necessitate a higher engine-room, since when a trunk piston is employed the head-room over the engine must be sufficient to allow the piston and connecting-rod to be lifted up clear of the engine, while with the crosshead type only the piston need be lifted clear, as it can be easily disconnected from the piston-rod. The advantages are, obviously, of much more importance with large engines than with small ones, but few engineers, we imagine, will dispute the firm's statement that increased reliability, economy, and smoothness of working are of far more consequence than the slightly increased first cost.

Optical Pyrometer.—The Cambridge Scientific Instrument Company, Limited, of Cambridge, have sent us a leaflet dealing with the Cambridge optical pyrometer, which is suitable for the measurement of temperatures ranging from 700 to 4000 deg. Cent., under industrial conditions, as well as for research work. The pyrometer depends for its action upon the relationship between the intensity of the light emitted by hot bodies and their temperature, and is based on the formulæ of Paschen and Wien. It comprises a telescope mounted on a tripod stand and containing an electric lamp which gives a uniform illumination over one half of the field of view, while the image of the hot body is visible in the other half. By turning the eye-piece a system of lenses and prisms in the telescope is adjusted until the two parts of the field are equally bright, and when this has been done, the temperature is read on a scale over which a pointer is moved by the action of turning the eye-piece. The lamp is supplied with current from a portable accumulator, and as it is, of course, essential that the light from the lamp should be kept constant, a small ammeter and rheostat are provided to enable the current to be regulated for this purpose. An amyl-acetate lamp is also provided to enable the lamp to be calibrated from time to time, so that the ageing of the filament can be allowed for; this test, of course, need only be made at fairly long intervals. The pyrometers can be supplied with one or more temperature scales of any desired range between the above-mentioned limits. They are claimed to give very accurate results, and to be very simple and convenient to use.

Electric-Lighting Connections.—We have recently received from Messrs. A. P. Lundberg and Sons, of Pioneer Electrical Works, 447 to 489, Liverpool-road, Islington, N., a copy of the fourth edition of their little booklet on "Electric Lighting Connections," the object of which is to show how the firm's special switches and other fittings may be employed to increase the convenience of electric-light installations. Since it was first published in 1912, 35,000 copies of the booklet have been issued, and these, in conjunction with the firm's scheme for examining contractors, wiremen, students and others on its contents, must have had considerable effect in spreading knowledge on the subject. There is, however, still need for further propaganda, and this is perhaps best evidenced by the comparative rarity with which the simple method of controlling a lamp, or group of lamps, from two points by means of a pair of two-way switches is employed. This device, which is only an example of many others, might be used with advantage in almost every installation, and yet many users of electric light are probably not aware of its existence. Wiring contractors will therefore benefit themselves and the electrical industry in general by bringing these modern switching methods to the notice of their clients, to many of whom the greater convenience would appeal even more strongly than the other advantages of electric lighting. A few minor corrections and additions have been made to the present edition of the booklet, and a chapter on automobile controls has also been added; the price, however, remains at 6d. net, or 7d. post-free.

Engineering Work in India.—A booklet entitled "Made in India," which has reached us from Messrs. Burn and Co., Limited., of Howrah, near Calcutta, illustrating some selected examples of this firm's productions, is particularly interesting at the present time when more attention than usual is being given to the industrial development of British Colonies and Dependencies. The firm possess large and well-equipped works at Howrah, employing over 5000 workmen, and including general engineering shops with iron and brass foundries, structural iron and steelwork shops, railway carriage and wagon shops, and a shipyard capable of building river steamers, barges, pontoons, &c., up to 280 ft. in length. The railway shops can turn out 1500 broad-gauge wagons and 100 carriages per annum, and the structural department is capable of dealing with bridges up to 350 ft. span. Among the illustrations in the booklet are included reproductions from photographs of dining-saloons and passenger coaches, steel goods wagons, forgings for railway carriages and wagons, drop-forgings, pressed-steel goods, caissons, buoys, bridges, river tugs, passenger steamers, marine engines, pumps, bridges, roofs, pipe-lines, tanks, pit-head gears, winding-engines, cranes, heavy castings, ornamental cast-iron work, &c., all of which were constructed at the Howrah works. This list, however, is not by any means exhaustive, as almost any kind of engineering work is undertaken by the firm. We imagine that some of our readers may be surprised to learn that works of this nature exist in India, and the knowledge may be of use to them in dealing with clients in that country. The firm have offices in London at 7, East India-avenue, Leadenhall-street, E.C.

LARGE MOLYBDENUM MINES IN NORWAY.—The large molybdenum mines in Phelomarken, in Norway, which have been worked in a somewhat primitive manner, have now been sold to a limited company. Before the war broke out the price was 4 kr. per kilog., whereas it is now 18 kr. (1*l.*) per kilog. (2.2 lb.). The company has already undertaken a considerable number of borings, to a depth into the mountain of some 70 metres, and molybdenum has been found everywhere. The Dalen mines are the largest deposits of this description so far discovered. Also the quality is satisfactory; at the Kvina molybdenum mines the rock contains on an average 10 per cent. molybdenum, and at the Dalen mines the percentage is expected to prove even higher. The new company has ordered plant, and an arrangement has been made for working under the Elmore patents. The crushing-machines so far ordered have a crushing capacity of 100 tons per 24 hours, and the washing plant will probably be kept going throughout the 24 hours. The product will contain about 97 per cent. molybdenum, but it is under contemplation to start a ferro-molybdenum works for the production of pure molybdenum according to a Swedish patent.

THE HÉROULT ELECTRIC STEEL FURNACES.—The following table on the use of the Héroult electric steel furnace throughout the world is given in the *Iron Age*:—

Countries.	Annual Capacity.		Increase in 1915.	Number of Furnaces.
	1914.	1915.		
	metric tons	metric tons	metric tons	
United States ..	141,200	371,500	230,300	40
Germany ..	385,750	403,750	18,000	17
Great Britain ..	77,000	189,800	112,800	20
Canada	6,000	21,600	15,600	3
France	194,500	234,800	40,300	11
Belgium ..	30,000	30,000	—	2
Luxemburg ..	40,000	43,600	3,600	2
Austria-Hungary	61,500	74,100	12,600	10
Switzerland ..	2,500	2,500	—	1
Italy	41,000	54,000	13,000	4
Russia	30,000	30,000	—	3
Sweden	6,000	14,700	8,700	2
Total	1,015,450	1,470,350	454,900	115

In increased tonnage in 1915, the Héroult furnaces of the United States lead with 230,300 tons, which is over half of the increase for the world. In total capacity Germany is first; however, if the large 30-ton furnace of the Dortmund Union, at Dortmund, Germany, with a yearly capacity of 120,000 tons, be eliminated, the United States would easily rank first in Héroult tonnage capacity. This furnace was listed as contracted for a year ago, and has not been reported as active yet, and may not be operated for some time. The marked increase in England's Héroult furnace capacity is to be noted—112,800 tons in 1915.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

SELECTED ABSTRACTS OF RECENT PUBLISHED SPECIFICATIONS UNDER THE ACT OF 1907.

The number of views given in the Specification Drawings is stated in each case; where none is mentioned the Specification is not illustrated.

Where inventions are communicated from abroad, the Names, &c., of the Communicators are given in italics.

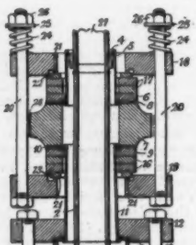
Copies of Specifications may be obtained at the Patent Office, Sales Branch, 25, Southampton Buildings, Chancery-lane, W.C., at the uniform price of 6d.

The date of the advertisement of the acceptance of a Complete Specification is, in each case, given after the abstract, unless the Patent has been sealed, when the word "Sealed" is appended.

Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any of the grounds mentioned in the Act.

ELECTRICAL APPARATUS.

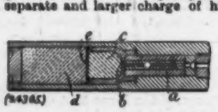
23,122/14. The British Thomson-Houston Company, Limited, London (*General Electric Company, Schenectady, U.S.A.*). **Rectifying-Devices.** [1 *Fig.*] November 26, 1914.—The present invention relates to the construction of vacuum-tight insulating seals which are of particular utility in high-powered vapour electric devices provided with a metallic container. One of the main difficulties experienced in this class of device is the maintenance of a perfect gas-tight condition of the seals at the electrodes, as the temperature variation in the course of ordinary operation is considerable. According to this invention, an insulating seal is provided, having metal bodies or rings bearing on the porcelain or other insulation, said bodies or rings having a coefficient of expansion substantially equal to that of porcelain or whatever insulation is employed in the seal. Referring to the drawing, the anode 1, consisting of steel, tungsten, or other metal, is welded to a steel tube 2 and is located within an anode arm or side chamber 3 of the rectifier. A threaded ring 4 is welded to the upper end of the tube 2 and to a relatively thin-walled tube 5 consisting preferably of soft steel or other metal of relatively low heat conductivity. A ring 6, consisting of a metal, such as nickel steel, having substantially the same coefficient of expansion as porcelain, is welded to the opposite end of the tube 5, and this ring 6 bears upon a section of porcelain insulation 7 with the interposition of suitable washers 8 of aluminium, lead, or like soft metal. Upon the opposite and lower side of the porcelain ring 7 bears another ring 9 of nickel steel, suitable washers 10 being here also used. To the ring 9 is welded a thin-walled tube 11. To the opposite end of the tube 11 is welded a



ring 12, consisting of iron or steel, and drawn against the anode-chamber wall 3 by means of bolts 13 passing through the ring 12 and through a ring 14 attached by screw-threads or otherwise to the metal anode tube 2. Here also suitable washers 15 are used. Bearing on the nickel-steel rings 6 and 9 are rings of insulation 16, 17, such, for example, as a composition of asbestos and calcium silicate, described in Specification No. 19,035, of 1905. Pressure is applied upon the rings 16, and thus upon the seal, by drawing together the rings 18, 19 by bolts 20. In order to distribute the pressure squarely upon the seal, the rings 18, 19 preferably are provided with rounded ridges 21, which bear upon the centre of steel rings 22, 23, these rings in turn bearing respectively against the insulating sections 17, 16. In order to make the pressure continuous, stiff springs 24 are preferably interposed between the washers 25 and the ring 18, these springs being compressed by tightening the nuts 26. A quantity of liquid, for example, mercury, may be placed in the tube 2, and this may be kept heated by suitable means, not illustrated and not forming a part of the present invention. A tube 27 has been indicated partly broken away, joined to the anode tube and serving to condense the mercury vapour. A steel wire 28 may be tightly bound around the porcelain to increase its mechanical resistance to strains and prevent cracking. The described construction prevents overheating and sudden changes of temperature of the seal, as heat from the anode tube 2 and the container-wall 3 enclosing the anode can reach the seal by conduction only through a relatively long path of poor heat conductivity afforded by the tubes 5 and 11. The resiliency of these thin-walled tubes also reduces mechanical strains on the seal. (*Sealed.*)

GUNS AND EXPLOSIVES.

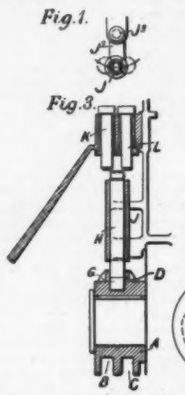
24,305/14. R. H. S. Bacon and J. H. Mansell, Coventry. Projectiles. [1 *Fig.*] December 18, 1914.—It has already been proposed to employ in a fuse for a projectile a charge of high explosive, such as trinitrophenylmethylnitramine or tetryl, and a separate and larger charge of high explosive.



According to this invention, this second and larger charge is divided into two portions, of which that portion which is nearer to the first charge is composed of loose explosive, while the other portion is composed of compressed explosive. *a* is a charge of compressed tetryl, behind which is a diaphragm *b*. *c* is loose tetryl, which is separated from compressed tetryl *d* by a wad or disc *e*. (*Sealed.*)

GAS-ENGINES, PRODUCERS, HOLDERS, &c.

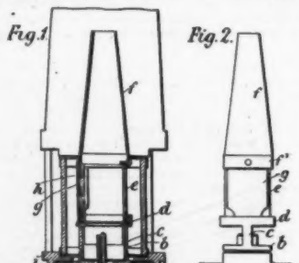
3394/15. Sunbeam Motor-Car Company, Limited, L. Coatalen, and H. C. M. Stevens, Wolverhampton. Internal-Combustion Engines. [5 *Figs.*] March 2, 1915.—This invention relates to valve-operating mechanism for internal-combustion engines, and it has for its object to provide a very simple mechanism whereby two valves, or the equivalent, are actuated from a single cam of a special type. The mechanism used consists of a double-grooved cam and two valve-tappets, and, according to this invention, there is employed between the cam and the tappets a single lifter, which slides endwise in a guide, and, with the guide, is capable of moving across the cam so as to bring the lifter under the two tappets as the lower end of the lifter moves across from one groove of the cam to the other. There is fixed to any suitable shaft the cam A having two grooves B and C, which intersect at the point D. The grooves are of



irregular shape, so that two cams E and F are formed. Engaging the grooves is a slipper G on the foot of the lifter H. This lifter works in a guide J, which is carried by arms J^2 from a pivot J^3. Consequently the lifter can swing, as shown in *Fig.* 3, permitting the latter to engage either cam-groove B or C. When the lifter is in the left-hand groove it engages the left-hand tappet K, and when in the right-hand groove the right-hand tappet L is actuated. Each tappet actuates a valve in the well-known manner, and it will be clear that as the cam rotates, or as the lifter revolves in relation to the cam, first one tappet K will rise and fall and then the other will be operated. Obviously, in place of the guide J rocking about a pivot it may be arranged to slide across the cam. In this way a single lifter sliding endwise in a bearing-guide and a single cam can be employed to actuate two tappets and two valves. The invention may be employed in engines having radial cylinders, in which case either the cylinders may rotate in relation to the cam, or *vice versâ*. (*Sealed.*)

MINING, METALLURGY, & METAL-WORKING.

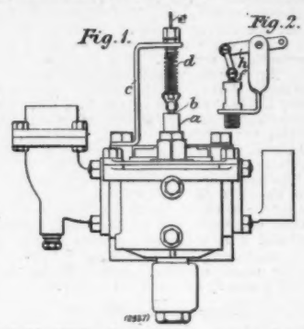
2041/15. John Davis and Son (Derby), Limited, and W. H. Davis, Derby. Miners' Safety-Lamps. [3 *Figs.*] February 25, 1915.—This invention relates to the type of lamp in which an inner glass is employed, and has for its object the provision of a simple means of carrying or securing such glass in position whereby said glass may be readily removed or replaced. The invention consists in the provision for the purpose of carrying the inner glass, of a gallery on pillars connected to a ring secured to the oil vessel of the lamp. The ordinary burner-attachment ring is replaced by a similar device *b* carrying on pillars *c* or the like a gallery *d*, between which and the oil vessel there is a sufficient space to admit the necessary air for combustion purposes. The inner glass *e* is carried in any suitable



manner by this gallery, and is preferably enveloped at the top by the lower end f^1 of the chimney *f*, the whole constituting the combustion-tube; these parts are arranged separately from the two gauzes or other parts of the lamp, so that upon unscrewing the oil vessel *i* from the upper or outer part *k* of the lamp the chimney *f* and inner glass *e* are withdrawn with the oil vessel and are immediately accessible. A reflector *g* of any suitable description may also be provided, and the latter with the chimney *f* and inner glass *e* may be secured together and in position as follows:—An upwardly-extending plate *h* may be fixed to the gallery *d*, to engage and hold a reflector *g* depending from the lower part f^1 of the chimney *f*, said reflector sliding down and being held by the sides or otherwise secured to the above plate; the inner glass being surrounded at the top by the lower part f^1 of the chimney *f*, the whole is thus securely held in a central position. (*Sealed.*)

MOTOR ROAD VEHICLES.

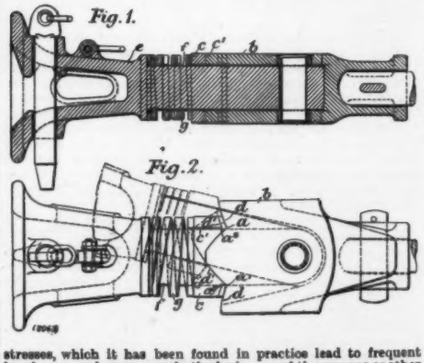
2557/15. The Bristol Wagon and Carriage Works Company, Limited, and E. C. Cook, Bristol. Motor Road Vehicles. [1 *Fig.*] February 17, 1915.—This invention relates to valves for the control of air to induction pipes or carburettors of internal-combustion engines from the driver's seat. A valve made in accordance with this invention comprises a long tapered spring-pressed plunger adapted to extend into a hollow cylindrical orifice on either a part of any existing carburettor or in a separate cylindrical orifice, formed in or fitted to any induction pipe, the said plunger being operated by a Bowden wire or other suitable mechanism. In Fig. 1, *a* is a movable throttle-spindle; *b* is a long tapered plunger which extends into the hollow cylindrical orifice of said spindle; *c* is a bracket which forms an abutment to the spring *d*; *e* is the wire which lifts the plunger *b*



out of the movable throttle-spindle *a*. The spring *d* normally keeps the plunger *b* on its seat whatever the position of the spindle *a*. The wire *e* is retracted against the action of the spring *d* by a Bowden-wire lever in the well-known manner, and this lever may be placed so that it can be operated from the driver's seat. In some cases a cylinder is fitted to the induction-pipe, and in such cases the tapered plunger fits into the cylinder and is adapted to be retracted by a Bowden wire. In Fig. 2, the tapered plunger *f* is operated by lever *h* controlled by a rod or other suitable operating device. (*Sealed.*)

RAILWAYS AND TRAMWAYS.

2043/15. Edgar Allen and Co., Limited, and H. D. Boyd, Sheffield. Central Buffers and Couplings. [2 *Figs.*] February 9, 1915.—This invention relates to a type of central buffer and coupling in which the square shank of the head is pivoted in and abuts up against the end of a cavity in the sliding cross-head of the apparatus. The shank of the head is pivoted so as to allow a radial movement in the cross-head, as when the vehicle is passing round curves; and in order to restore the head to its central position, the outer end of the cross-head is formed with one or more extended indentations or V-shaped grooves; and fitting on the square shank of the head is a rectangular block with one of its faces correspondingly formed with one or more V-shaped projections adapted to engage with the V-shaped groove or grooves in the end of the cross-head. Between this last-named V block and the rear flange of the buffer-head is placed a square coiled spring which encircles the shank of the buffer-head. When the buffer-head is turned to one side or the other, as when the vehicle is going round a curve, the V block is caused to slide up one side of the V-shaped indentations on the cross-head, which movement, in conjunction with the inclination of the buffer-head and shank, causes the spring to be severely compressed at one side, while the other side remains uncompressed. The V block compressing the spring on one side only also tends to press the spring against the buffer-shank, on the side on which it is compressed, causing it to bind on the corners of the shank. These actions on the spring set up severe



stresses, which it has been found in practice lead to frequent breakages, and consequently the laying up of the wagons or other vehicles with which the buffers are employed, to have new springs fitted. The object of the present invention is to overcome the objection due to this frequent breakage of the springs, and according thereto the sliding surfaces of the end of the crosshead and the V blocks are so constructed that no matter to what angle the buffer-head and shank may be turned, the front edge of the V block is always maintained at right angles to the centre line of the shank; consequently the spring encircling the shank is always evenly compressed on both sides, thus obviating the liability to break. Instead of forming the V-shaped indentations *a* and a^1 on the end of the crosshead *b*, and the V-shaped projections a^2, a^3 on the V block *c* with straight faces, as is the present practice, they are formed with curved faces *d* and d^1 respectively, of such a shape that when the buffer-head *e* and shank *f* are turned to one side, as when going round a curve, the curved faces *d* and d^1 of the crosshead *b* and the V block *c* remain in contact, and the front edge of the V block *c* is at right angles to the centre line of the buffer-head *e* and the shank *f*. It is thus obvious that both sides of the spring *g* will be subjected to the same amount of compression. The wear on the curved faces will also only be comparatively slight, as the buffing shocks are not transmitted through them, as is the case in some kinds of apparatus of this type as at present made. Hitherto it has been necessary to form the internal faces a^1 of the V block *c* with two oppositely sloping faces, to allow for the inclination of the shank in turning. By this invention such formation is unnecessary, as the V block may have its internal face parallel with the faces of the shank, as at whatever angle the shank is placed, the V block occupies the same relative position to it. (*Sealed.*)